Acta Orthopaedica Scandinavica

Vol 47, Nos 1-6 1976

MUNKSGAARD, Copenhagen

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Munksgaard
International Booksellers and Publishers, Ltd
35 Nørre Søgade, DK 1370 Copenhagen K, Denmark

PRINTED IN DENMARK VALD PEDERSENS BOGTRYKKERI A S COPENHAGEN

ACTA ORTHOPAEDICA SCANDINAVICA

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increasing number of publications rthopaedic surgery—books, reports periodicals—indicate the flourishing lopment within orthopaedic practice research It is with great pleasure we welcome the Italian Journal of iopaedics and Traumatology, edited Ir E A Nicoll, as a member of the rnational orthopaedic concert

cta, approaching its fiftieth volume, reflected, like other journals, the ids and developments within the speity from case reports, the problems of letal tuberculosis, polio management, l arthrodesis through the sphere of imatology into the recent phase focuson joint reconstruction and on funda ntal research

The growth of our speciality has also en experienced by Acta The number of iorts submitted is increasing and the le of subscribers is still growing ithin the past decade the number of bscribers has increased from 1517 to 13 and the individual volumes from pages to 1035 pages

The Acta Board welcomes authors, ders and advertisers to Acta in its new mat, which has been adopted as a tical measure To the reader it facil-s diagonal reading To the publisher neans a practical change Certain es and figures may be accommodated hin one column instead of spanning a page Admittedly, to the careful col-or the change is a nuisance, which we rtainly regret We have however endeavoured to keep the dimensions as close as technically possible to those of the past volumes

The new structure also places demands on our contributors, the number of reports submitted for publication is increasing rapidly Due to the limited capacity we urge our contributors to consider before submission Did I respect the instructions? Did I provide sufficient scientific support for my conclusions? Did I condense my message so as to occupy a minimum of space? We must unfortunately reject a rather high percentage of contributions because the above questions have not been sufficiently considered or appreciated

It should also be taken into consideration that the increasing quantity of new publications does present a problem to the orthopaedic surgeon and articles must be carefully adjusted in conformity with the amount of new information submitted The aim of the editorial board of Acta, therefore, will continue to be the publication of short and well-documented articles making it easier for the orthopaedic surgeon to survey the scientific developments in the field

During 1975 Acta had the pleasure of collaborating with SICOT in publishing the "Review Lectures" presented at the Copenhagen Congress The response to that special issue has encouraged the board to publish editorials or surveys on pertinent subjects in the same way Indeed, the Acta board envisions a fertile

future collaboration with all who wish to cement the structure of orthopaedic science and service both established and emerging

Knud Jansen

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SSUE REACTION TO METHYL METHACRYLATE MONOMER

A Comparative Study in the Rabbit's Ear on the Toxicity of Methyl Methacrylate Monomer of Varying Composition

L RS LINDER

Laboratory of Experimental Biology Department of Anatomy
University of Goteborg Sweden

The a m of the present investigation was to evaluate if a bone cement monomer with a high concentration of accelerator (N N dimethyl p toluid ne) is more toxic than a methyl methacrylate monomer free from accelerator 1) No difference in the acute local toxicity between CMW ® Simplex P® and pure methyl methacrylate monomer was seen 2) By gas chromatography N N dimethyl p tolu dine was shown to be water soluble to a small extent Any bone cement monomer in current use can be fully d ssolved in saline to a concentration of about 1 per cent

Key words bone cement monomer local toxic ty N N d methyl p tolu d ne water solubil ty

Accepted 8 viii 75

ne monomer of today s acrylic bone ements is made up of methyl methacryl ate (MMA) monomer To this are added minute amounts of stabilizer (hydro quinone ascorbic acid) and accelerator (N N dimethyl p toluidine) The cements ost widely used are CMW ® Palacos ® J Simplex ® Their monomers differ omewhat in composition (Table 1)

It is known that MMA monomer is ytotoxic (Hoppe 1956 Mohr 1958 Hul iger 1962 Schlag et al 1973) It is also nown that leakage of MMA monomer nto the tissues takes place from the surface of the implanted bone cement (Homsy et al 1972 Wenzl et al 1973 Sulzner et al 1974) The greater part of this monomer leakage takes place while the cement still has its pasty consistency that is during the very first minutes after implantation After the cement is polym erized only minute amounts of residual monomer are released for possible toxic action (Smith & Bains 1956 Lee et al 1973) An acute local chemical tissue in jury thus seems unavoidable but its magnitude and its functional conse quences are not fully known

Hulliger (1962) has studied the effect in tissue cultures of Palacos ® monomer and pure MMA monomer and concluded that both have the same toxicity How ever more recent work on Palacos ® has suggested that the accelerator N N dimethyl p-toluidine (NNDPT) makes Palacos ® more toxic than pure MMA

his study was supported by grants from Hjal nar Svenssons Forskningsfond

Table 1 Composition of the monomer of the most widely used types of bone cement as well as the pure monomer used in the study The figures are provided by the respective manufacturers

	N, N-dimethyl-p-toluidine	Hydroquinone	Ascorbic acid	MMA
Simplex P®	2 6 %	75 ± 15 PPM	—	balance
CMW®	1 0 1 5 %	5 — 10 PPM	0 02 %	balance
Palacos®	0 7 %	60 PPM	—	balance
Pure	–	0 1 PPM	—	balance

(Schlag et al 1973) If such a difference in monomer toxicity is caused by the addition of NNDPT, it would be even more marked in the case of Simplex-P® and CMW®, since Simplex-P® contains three to four times as much NNDPT as Palacos®, and CMW® twice as much (Table 1)

It is of practical importance to keep the monomer toxicity as low as possible Therefore, it seems justified to evaluate if the Simplex-P® and CMW® monomers have a toxicity which obviously differs from that of pure MMA monomer In the present study, these three monomers have been compared with regard to their local tissue effects Palacos® has an accelerator content intermediate to those of Simplex-P® and pure MMA, and since its toxicity, therefore, can also be expected to be intermediate, Palacos® has not been included in the study

The microvascular system is a sensitive indicator of tissue injury, and microangiography of the rabbit's ear has proved valuable in studies on the local tissue irritancy of various drugs (Brånemark 1967, Brånemark et al 1969) This technique gives a picture of the reparative process following tissue injury, but information on the acute tissue effect can also be gained

MATERIAL AND METHODS

CMW® Simplex-P® and pure MMA (kindly supplied by AB Bofors Nobelkrut, Sweden) monomer were used in the study Four concentrations of each monomer were tested 100 per cent monomer and 2 per cent, 1 per cent and 0 5 per cent v/v dilutions in isotonic saline (for technical details, see below)

Sixteen male, albino rabbits, weight 1 5 kg age 3 months, were used The animals were divided into four equal sized groups, one group for each monomer concentration tested

Each animal received two 0 05 ml injections sub perichondrally on the outer surface of each ear, one injection proximally and one distally Three of the four injections thus given to each animal contained the three monomers, the fourth (iso tonic saline) serving as a control of the trauma produced by the injection procedure In all groups, each monomer was injected proximally twice and distally twice

In an additional series a 0 03 per cent v/v solution of N, N dimethyl p toluidine (Fluka AG, Switzerland) in isotonic saline was com pared to isotonic saline with regard to the local tissue reaction Four rabbits were used The NNDPT solution and the saline solution were alternately injected proximally and distally in the ears Eight injections of each solution were made *The NNDPT concentration was chosen so* that it would approximately equal the NNDPT concentration of the 1 per cent Simplex P® solution

The animals were regularly inspected and the tissue reaction seen on transillumination of the ears recorded After 8 10 days the animals were submitted to microangiography Under urethane anaesthesia, 500 ml of a 50 per cent saline suspension of barium sulphate (Mixobar®, Astra, Sweden) were infused into the abdominal aorta in the retrograde direction The jugular veins were opened to balance the infused volume, Repeated injections of heparin and lidocain through the infusion catheter were made to facilitate the filling of small calibre vessels The ears were then radiographed by means of a Machlett OEG 50 tube on Kodak MR plates at 15 mA, 12 kV and a film focus distance of 12 cm The exposure time was 15 minutes Histological sections, 4 μ in thickness stained with haemotoxylin eosin, were taken from rep resentative ears

Figure 1 Microangiograms of rabbit ears exposed to different concentrations of MMA monomer A 100 per cent monomer A large central area devoid of small vessels (indicating necrosis) with surrounding vascular reaction (typical of granulation tissue) B 2 per cent monomer Less extensive vascular reaction and more superficially located necrosis C 1 per cent monomer A small area with a vascular architecture typical of granulation tissue is seen at the arrow







Technical

The CMW ® and Simplex P ® monomers were sterile from the manufacturer The pure MMA monomer was not sterilized and every attempt at membrane filtration failed as the filters were destroyed by the monomer However since the monomer is considered to be self sterilizing (Charnley 1972) no further attempts were made Once taken from their original containers all three monomers were treated aseptically Glass syringes were used throughout

The 2 1 and 0 5 per cent monomer concentrations were obtained by mixing 2 1 and 0 5 ml of the 100 per cent monomer with 100 ml of isotonic saline The 2 per cent mixture became opaque on shaking whereas the others were clear

The solubility in water of MMA monomer is 1 59 g/100 g at 20° C (Riddle 1954) and of hydroquinone 7 4 g/100 ml at 25° C (May & Baker Ltd Dagenham England) No figure on the solubility in water of NNDPT has been obtained

In order to evaluate if the NNDPT of the monomers tested was dissolved or suspended in the saline its solubility in a 1 per cent aqueous monomer solution was determined (This part of the study was done by L. Harthon and L. Kullberg AB Bofors Nobelkrut Sweden)

A 1 per cent water solution of the pure MMA monomer was prepared The solution was then saturated with NNDPT Gas chromatography was performed with a Perkin Elmer F 11 gas chromatograph equipped with a flame ionization detector The operating conditions were as follows

Column ¼" glass packed with 20 per cent SF 30 on Chromosorb W
Oven temperature 130° C.
Injection temperature 250° C
Carrier gas N_2
Carrier gas flow rate 40 ml/min
Sample size 1 0 µl

The MMA peak was used as an internal standard and the NNDPT peak was related to that of the MMA in the subsequent calculations

RESULTS

100 per cent monomer On injection there was a marked tendency for the monomer to spread in the tissues Within a minute, bleeding occurred in the area occupied



Figure 2. Histology of rabbit ears exposed to different concentrations of MMA monomer. The left part of the pictures represents the centre of the tissue reaction, the right part showing the periphery of the reaction

A. 100 per cent monomer Centrally, a large fibrinous crust is seen (*). Peripheral to this, granulation tissue is found (at arrow). Htx-eosin, × 20

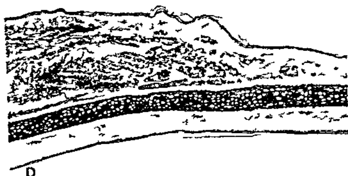


B. 2 per cent monomer Centrally, a small fibrinous crust is seen at the skin surface (*). Granulation tissue (indicated by arrow) is present below the skin and extends below the cartilage Htx-eosin, × 40



C Detail of B, showing active granulation tissue with round cells and scattered fibroblasts in a loose stroma Numerous vascular channels are present, two of which are indicated by arrows The channels appear granular because of their content of barium sulphate Htx-eosin, × 280

by the monomer (diameter about 1 cm) A few hours later, an anaemic zone was seen in the centre of this area, the rest of the ear being strongly hyperaemic By 24 hours, exudation onto the skin had begun from most injection sites At sacrifice, it was evident that necrosis through the entire thickness of the ear had taken place at the distal injection sites in all cases, whereas, at the proximal injection sites, the skin of the inner surface of the ear usually was intact



F gure 2 D 1 per cent monomer Granulat on t ssue not extend ng below the cart lage is seen centrally Htx eos n × 40

The microangiograms revealed a central zone practically devoid of vessels surrounded by a hypervascularized zone where a large number of small newly formed vessels with irregular topography and varying diameter dominated i e a microvascular picture typical of granulation tissue (Figure 1 A)

Histologically there was a large central necrotic area occupied by a fibrinous crust extending through the ear Bordering this crust was a line of round cells peripheral to which granulation tissue was found (Figure 2 A) Further away from the centre of the tissue injury a rapid transition to a normal histological picture was noted

No difference in the tissue reaction of the three monomers was seen

2 per cent monomer After injection the mixture stayed in a well defined circumscribed area Macroscopically the same sequence of events occurred as in the 100 per cent group only to a far lesser degree Exudation took place at all injection sites in three out of four animals In the fourth animal only a local reddening equally prominent for all monomers persisted at the end of the experiment

Microangiographically a small vessel free zone with surrounding vascular reaction was seen where exudation had occurred (Figure 1 B) in the other test regions there were vessels even in the central area

Histologically where exudation had taken place a small central fibrinous crust was present above the cartilage Granulation tissue was found peripheral to this area and to a smaller extent also below the cartilage (Figure 2 B and C) Where exudation did not occur the skin of the upper surface of the ear was intact and only the area above the cartilage was occupied by granulation tissue

There was no difference in the reactions of the three monomers

1 per cent monomer Macroscopically only mild reactions were seen A local reddening was the typical picture No exudation occurred In some cases the reddening disappeared during the observation time so that at the end of the experiment the area looked normal However the disappearance of this reaction always took place several days after that of the unspecific reaction produced by the saline control injections

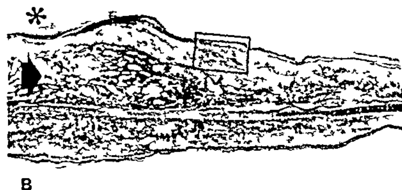
Microangiographically where a reddening was present a local hypervascularization was seen (Figure 1 C) If the macroscopical reaction had disappeared a normal vascular architecture was present

Histologically where the tissue reaction persisted granulation tissue was seen above the cartilage The overlying



Figure 2 Histology of rabbit ears exposed to different concentrations of MMA monomer The left part of the pictures represents the centre of the tissue reaction the right part showing the periphery of the reaction

A 100 per cent monomer Centrally a large fibrinous crust is seen (*) Peripheral to this granulation tissue is found (at arrow) Htx eosin × 20



B [illegible] per cent monomer Centrally a small fibrinous crust is seen at the skin surface ( ) Granulation tissue (indicated by arrow) is present below the skin and extends below the cartilage Htx eosin × 40



C Detail of B showing active granulation tissue with round cells and scattered fibroblasts in a loose stroma Numerous vascular channels are present two of which are indicated by arrows The channels appear granular because of their content of barium sulphate Htx eosin × 280

by the monomer (diameter about 1 cm) A few hours later an anaemic zone was seen in the centre of this area the rest of the ear being strongly hyperaemic By 24 hours exudation onto the skin had begun from most injection sites At sacrifice it was evident that necrosis through the entire thickness of the ear had taken place at the distal injection sites in all cases whereas at the proximal injection sites the skin of the inner surface of the ear usually was intact

In some cases granulation tissue was formed indicating a serious tissue injury but in a number of cases only an unspecific local reaction was noted The 0.5 per cent dilution in no case caused a registrable reaction The 1 per cent dilution thus, seems to correspond to the tissue reaction threshold However, under other experimental conditions, the reaction threshold may be altered, and, consequently, the absolute figures of the present study cannot be safely used for extrapolation to other animal species or tissues

The fact that the reaction pattern to the monomers was not uniform in the 1 per cent group can probably be ascribed to methodological errors, as it is logical to assume that such errors have more influence on the magnitude of the tissue reaction at the level of the reaction threshold It is unlikely that the lack of uniformity was due to differences in monomer toxicity Two findings support this view 1) The NNDPT, when tested separately in the same amount as in the 1 per cent Simplex P ® solution, caused no tissue reaction 2) The bone cement monomers, which contain NNDPT, caused less strong reactions than the pure MMA monomer The opposite pattern would have been expected

On the basis of the data obtained in the present study it seems reasonable to conclude that the acute local toxicity of the MMA monomer is so high that the possible additional effect produced by NNDPT is overshadowed This is in good agreement with the conclusions made by Mohr (1958) and Hulliger (1962) For practical purposes, thus the monomers of the bone cements used today can be considered to be of the same toxicity

The currently used bone cements have different polymerization peak temperatures and polymerization times (Homsy et al 1972) and consequently, may not be equal from a tissue injury point of view If variations in the acute tissue reaction to the cements are seen, however, it seems that differences in polymerization kinetics rather than in monomer toxicity are responsible

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skin and the cartilage were normal (Figure 2 D) If the reddening had disappeared, no histological changes were seen in the sections

In three out of four animals in this group, the reaction caused by the CMW ® and Simplex-P ® monomers disappeared during the observation time, whereas the reaction to the pure MMA monomer disappeared in only one of the same four animals

0 5 per cent monomer In no case could a tissue reaction be seen which differed from that produced by the saline control Microangiographically and histologically, the ears appeared unaffected

0 03 per cent NNDPT solution No macroscopical reaction was noted

Solubility of NNDPT In two experiments, the solubility of NNDPT in a 1 per cent w/w aqueous solution of pure MMA monomer was found to be 0 058 per cent and 0 047 per cent w/w respectively

DISCUSSION

The present study confirms all earlier reports that concentrated methyl methacrylate monomer is highly toxic to tissues in contact with it A fulminant tissue reaction and necrosis always followed its application However, as the aim of the study was to compare the toxicity of three monomers with different concentrations of N, N-dimethyl-p-toluidine, the reaction produced by the concentrated compounds could not serve as a basis for any conclusions Surely, differences in toxicity would have been overlooked because of the overwhelming reactions produced Therefore, the injected doses were lowered to the level of the tissue reaction threshold, since, if the toxicities are the same, the reaction thresholds should also be the same In order to keep the injection volumes constant, thereby equalizing the mechanical trauma, dilutions of the monomers were made Isotonic saline was used as vehicle, since it is one of the few solutions available which does not, in itself, cause tissue reaction

When dilutions of the monomers are discussed, the solubility in water of NNDPT is of interest The 2 per cent mixture clearly is a suspension of MMA monomer in saline, i e a fraction of the monomer is dissolved in the saline and another fraction exists in the form of small droplets in the fluid The lipid solubility of NNDPT is far greater than its water solubility Therefore, it is reasonable to assume that the NNDPT will be found mainly in the MMA monomer droplets of the suspension and to a far lesser degree in the water phase If only the droplets are evenly dispersed, the same proportion of MMA monomer and additives as in the concentrated monomer will be injected

In the 1 per cent and 0 5 per cent dilutions, the MMA monomer is fully dissolved In order to ensure an even distribution of the additives in the solution, it is desirable that these should be dissolved together with the MMA monomer The Simplex-P® monomer has the highest NNDPT concentration of the monomers tested (2 6 per cent), and a 1 per cent solution of Simplex-P ® holds an NNDPT concentration of 0 026 per cent The study has shown that an NNDPT concentration of approximately 0 05 per cent is obtainable in a 1 per cent MMA solution, and, thus, it is concluded that all components of the monomers tested were fully dissolved in the saline in the 1 per cent and 0 5 per cent groups The water solubility of NNDPT also means that the accelerator may leak into the tissues from the bone cement, but the clinical implication of this is unknown at the present time

The results of the study showed that the 2 per cent dilution caused tissue necrosis in all instances The response to the 1 per cent dilution varied somewhat

Acta orthop scand 47, 11–19, 1976

MECHANICAL PROPERTIES OF DRIED DEFATTED SPONGY BONE

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A study has been made of the compressive strength, compression at rupture, limit of proportionality, compression at the limit of proportionality and the modulus of elasticity of spongy bone from vertebrae and tibias The specimens were obtained from autopsy subjects of both sexes aged 14 to 89 years There was a qualitative deterioration of most of the strength parameters with age, and also differences between the sexes and between vertebrae and tibia Spongy bone was found to have the unusual mechanical property that, despite rupture, its compressive strength often steadily increased, this was especially the case for vertebrae from young males

Key words mechanical properties, spongy bone, apparent density, compressive strength, osteoporosis, age changes

Accepted 20 vii 75

The mechanical properties of spongy bone have received little attention in the literature Evans (1957) gives only one reference, viz Rauber (1876), who reported the respective compressive strengths for spongy bone from vertebrae and femoral condyles as 0 84 and 0 96 kgf/mm² for two groups, each of four specimens, with a range of about 20 per cent This examination of the mechanical properties of spongy bone has been carried out with special reference to any variations associated with age and sex

MATERIAL

Spongy bone was obtained from the lowermost two to four lumbar vertebrae and from the head of the tibia in 60 autopsy subjects In general specimens were taken from four men and four women in each age decade between 14 and 89 years The material has been described in detail elsewhere (Lindahl 1962), it has also been used for an examination of the degree of osteoporosis, which was determined by measuring the apparent density of spongy bone

METHODS

Fresh spongy bone was sawn into cubes measuring about 2×2×4 cm These were cleaned of blood and fat by repeated flushing with hot water and then leached in water for 48 hours, after drying, any remaining fat was removed with xylol and the cubes were then dried again and stored in air at 3-5° C. Before the mechanical tests the specimens were conditioned for 2 months at 65 ± 3 per cent relative humidity and 20 ± 1 0° C. From the specimens accurately rectangular test bodies were sawn The height in the axial direction of the pores was usually 10 mm sometimes slightly less and the base dimensions were 9–39 × 14–60 mm The compressive tests were carried out at the National Testing Laboratory in an Alwetron testing

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Figure 3 See Figure 1 Curve type D

conventional' material usually approximates closely to that for tensile strength tests the load/deformation curves for spongy bone are atypical and variable There is usually no difficulty in ascertaining the stress at which the material collapses but, unlike other substances, spongy bone usually undergoes no total loss of strength during rupture

For this material it is possible to distinguish three main types of stress variation, viz

(1) a steady increase until compression is discontinued, possibly after a small drop (type I, increase, Figure 1)
(2) largely constant stress after rupture throughout the period of compression (type E, equal, Figure 2), and

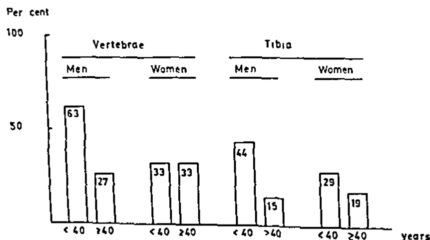


Figure 4 Percentage of type I curves for various groups (males females, vertebrae, tibia) for ages (< 40 and ≧ 40)

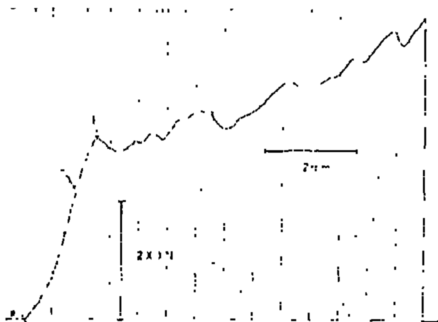


Figure 1. Stress/compression curve for spongy bone. Type I. A, The limit of proportionality between compressive force and deformation. B, Breaking point. The scales for the compressive force and deformation are entered on the curve.

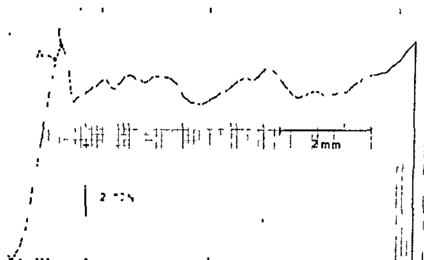


Figure 2. See Figure 1. Curve type L.

machine at a deformation rate of 0.05 mm/min. The compression in the axial direction was discontinued when the height of the test bodies had been reduced by two thirds. The strength parameters, including the compressive strength, limit of proportionality, compression at rupture and modulus of elasticity, were calculated as described in an earlier paper (Lindahl 1968).

Using these test bodies, compression at the *limit of proportionality* was also calculated. This is the percentage deformation of the original length of the body at the point where the proportionality of compression to applied force ceases (Point A, Figure 1).

For the mechanical properties of vertebrae, the values are recorded as the means of the values for test bodies from two to four lumbar vertebrae originating from the same subject.

The mean, standard deviation, standard error of the mean and coefficients of regression were calculated by the usual statistical methods (Snedecor & Cochran 1962).

RESULTS

The compression curves. Whereas the load/deformation curve obtained for

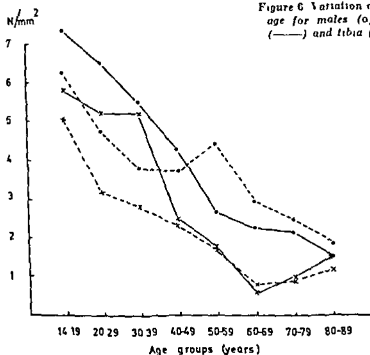


Figure 6 Variation of compressive strength with age for males (o) and females (x), vertebrae (——) and tibia (----)

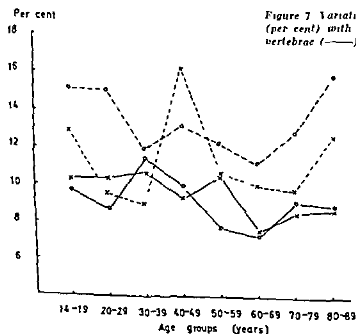


Figure 7 Variation of compression at rupture (per cent) with age Males (o) and females (x); vertebrae (——) and tibia (----)

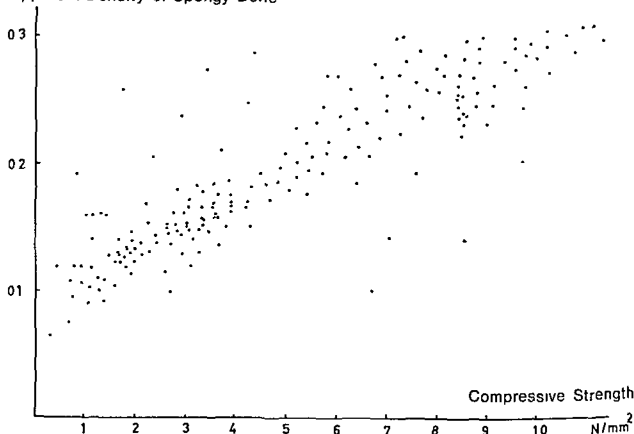


Figure 5 Relationship between apparent density and compressive strength of spongy bone Each point relates to one specimen

(3) after rupture a steady decrease in stress throughout compression (type D, decrease, Figure 3)

For 201 test bodies the distribution of types I, E and D was 38, 49 and 13 per cent, respectively, thus, type D was much less common than the other two From the aspect of biological and mechanical properties the first type of stress varia tion (I) is evidently superior to the other two, for in spite of the rupture, the strength of the compressed bone increased steadily Accordingly an examination was made of the distribution of this type of curve with respect to compressive strength, age and sex No connection could be traced between strong bone (with a high compressive strength) and bone with a "favourable" type I curve High and low strength were found in combination with all three types of curves There would seem to be tendency, however, for type I curves to be more common in the lower age groups, and more common in men than in women From comparisons of the frequencies of such curves made for the age groups < 40 and ≥ 40, for the two sexes and for vertebrae and tibia, presented in Figure 4, it is seen that they were more common in the lower age groups, in men rather than in women, and in vertebral rather than in tibial bone, and thus most common for vertebral specimens in young males These differences are not statistically significant

Relation between apparent density and compressive strength In an earlier paper the author proposed that the apparent density (the weight per unit volume of bone, including cavities), which is equiv-

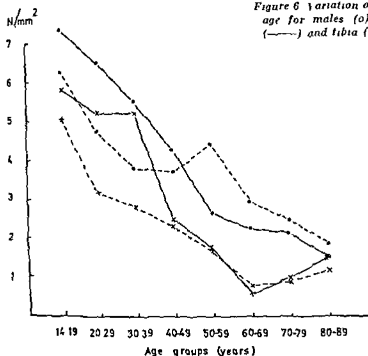


Figure 6 Variation of compressive strength with age for males (o) and females (x), vertebrae (——) and tibia (- - - -)

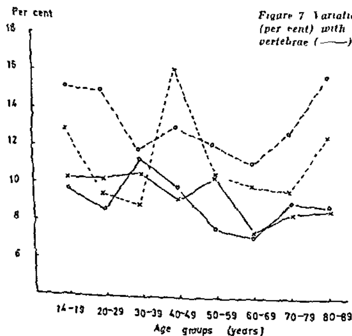


Figure 7 Variation of compression at rupture (per cent) with age Males (o) and females (x), vertebrae (——) and tibia (- - -)

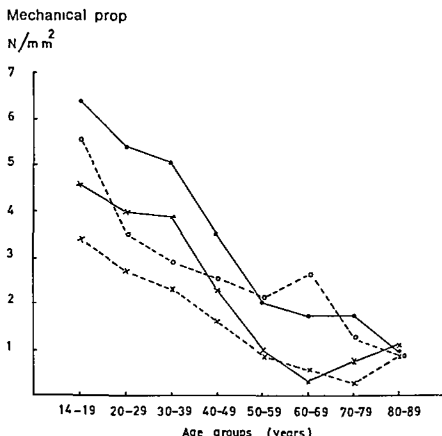


Figure 8 Variation of limit of proportionality with age Males (o) and females (x), vertebrae (——) and tibia (---)

alent to the porosity, reliably represents the degree of osteoporosis of spongy bone (Lindahl 1962) The compressive strength would presumably be inversely dependent on the porosity From the plot of compressive strength against apparent density for all 201 specimens (Figure 5) it is seen that there was a close correlation between these two parameters, this is statistically highly significant (***) with a correlation coefficient of 0 7

Compressive strength See Table 1 For both vertebrae and tibia there was a significant sex difference (**), the values being about 75 per cent higher for the men Since there is a relationship between compressive strength and apparent density it is conceivable that this sex difference was due solely to differences in apparent density When, however, the compressive strength was plotted against the apparent density—giving what may be termed the *"relative compressive strength"*—the sex difference remained, this means that besides the lower compressive strength in women, due to greater porosity of the bone, there was also a qualitative difference Spongy bone from the tibia and vertebrae in the same person did not differ in this respect The compressive strength decreased with age in both sexes and for both tibia and vertebrae (Figure 6) Here, too, calculation of the "relative compressive strength" showed a reduction with age that was less pronounced but still significant (**), this is indicative of an age-dependent change in quality unrelated to the porosity, this decrease amounted to about 20 per cent

Compression at rupture See Table 1 The values were higher for the tibia than the vertebrae, the difference for the

Table 1 Mechanical properties of spongy bone

	Males				Females			
	Vertebrae (n = 32)		Tibia (n = 32)		Vertebrae (n = 32)		Tibia (n = 32)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Compressive strength N/mm²	4.6 (0.2—10.5)	0.3	3.9 (0.2—6.7)	0.3	2.7 (0.3—7.0)	0.2	2.2 (0.6—4.8)	0.2
Compression at rupture per cent	9.5 (5.3—14.4)	0.4	13.4 (4.1—26.8)	0.8	9.0 (3.2—14.7)	0.6	11.6 (3.8—25.8)	1.1
Limit of proportionality N/mm²	4.0 (0.1—9.7)	0.1	2.8 (0.1—7.3)	0.1	2.2 (0.2—6.0)	0.1	1.5 (0.1—7.5)	0.1
Compression at the limit of proportionality per cent	6.7 (4.1—8.6)	0.2	8.3 (3.7—18.9)	0.7	6.1 (2.6—10.0)	0.4	6.9 (1.4—14.3)	0.6
Modulus of elasticity N/mm²	55.6 (1.1—139.1)	0.7	34.6 (2.5—74.4)	0.4	35.1 (5.2—103.6)	0.6	23.1 (1.4—73.2)	0.4

1 Newton/mm² (N/mm²) = 0.102 kilopond (kp) or kilogramme force/mm² (kgf/mm²) = 145 lb/in² (psi)

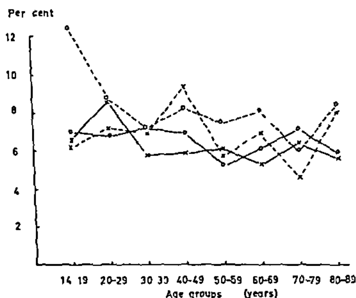


Figure 9 Variation of percentage compression at limit of proportionality (per cent) with age Males (o) and females (x) vertebrae (——) and tibia (– – –)

males was 41 per cent and highly significant (***), and for the females 29 per cent and not significant There was no sex difference, nor any change with age (Figure 7)

Limit of proportionality See Table 1. For both tibia and vertebrae the values were higher for men than women The difference was about 90 *per cent* and highly significant (***) The values were

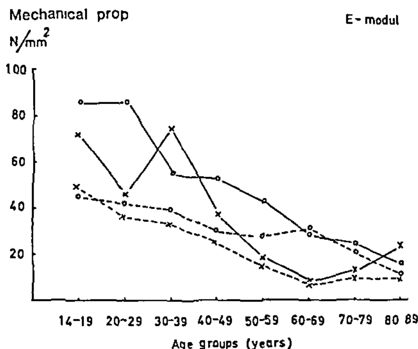


Figure 10 Variation of modulus of elasticity with age Males (o) and females (x), vertebrae (——) and tibia (– – – –)

higher for the vertebrae than for the tibia—also highly significant (***) From the graph in Figure 8 it is seen that there was a marked and highly significant (***) reduction with age of the order of 90 per cent

Compression at the limit of proportionality See Table 1 The sex difference was fairly small The values were highly significant (***) more so for the tibia than for the vertebrae There was no significant reduction with age (Figure 9)

Modulus of elasticity See Table 1 Comparison of the values for the vertebrae and tibia disclosed highly significant and higher (***) values for the vertebrae The values for men were higher than for women, but not at the level of significance There was a significant (**) reduction of 30 per cent with age (Figure 10)

DISCUSSION

One important benefit derived from this study is the complete set of data on various strength parameters for spongy bone Also of interest is the fact that, in spite of the rupture of spongy bone it retained, or in some cases even improved, its compressive strength Just as for compact bone, most of the strength parameters examined decreased with age, exceptions were the compression at rupture and the limit of proportionality

It might be wondered whether this impairment of quality with age might be due solely to a simultaneous lowering of the apparent density (resulting from an increase in porosity) Since, however, the reduction in the various strength parameters was considerably greater than the drop in apparent density, there must have been a direct change in quality as well as the increase in porosity with age A corresponding reduction in strength with age has been demonstrated for compact bone (Lindahl 1968) and these two trends account in some measure for the greater tendency for fractures to occur at advanced age

In addition, the compressive strength and limit of proportionality were greater

for men than women The fact that these differences were larger than could be accounted for by the sex difference in apparent density also points to a difference in mechanical quality

The difference between vertebrae and tibia is difficult to assess The former had a higher modulus of elasticity and limit of proportionality whereas the tibia had a higher percentage compression at rupture

The reason for these differences might be disclosed by further research in the subject but for the time being it must suffice to ascribe them to adaption to a difference in the functional demands on the two bones

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Acta orthop scand 47, 20–27, 1976

PHYSICAL PROPERTIES OF FLUOROSIS BONE

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The bones of two patients one with a moderate and one with a severe chronic industrial fluorosis (stage I II and stage III), and the bones of three control persons were examined The following parameters were determined the fracture load, the fracture load/unit area (resistance to pressure) of the body of the first lumbar vertebra the bending strength of the neck of the femur and of the lower third of the femur the fracture load/unit area and the modulus of elasticity of femoral slices 2 cm thick and of precisely defined cylinders from the femoral cortex The microhardness according to Vickers on the cross section of the femur was also determined The results obtained are discussed with regard to fluoride therapy of osteoporosis

Key words human industrial fluorosis, physical bone strength tests microhardness NaF therapy of osteoporosis

Accepted 8 vii 75

During investigations of workers in an aluminium smelting plant, who were suffering from chronic fluorine intoxication, increased hardness of the bone in biopsies of the iliac crest was noticed, even to the point of a breakdown, in one case, of the biopsy cannula In an autopsy of an aluminium smelter worker with pronounced fluorosis difficulty in sawing of bones was experienced (Franke 1968, 1973, Franke & Auermann 1972, Franke et al 1972 b, 1975) These findings are in contrast to those in animal fluorosis

These observations were of interest firstly with reference to our current attempts to treat osteoporosis by fluoride medication (Franke et al 1974) and secondly because of conflicting statements regarding the effect on the skeleton of water fluoridation with a view to caries prevention

Further studies are reported here on the physical properties of bone in fluorotic as compared to normal subjects

MATERIAL AND METHODS

Two aluminium smelter workers with different stages of industrial fluorosis were investigated The first case (F 1) was a 56 year old man who died as a result of a traffic accident after 14 years of fluorine exposure The roentgenographic examination showed stage III fluorosis according to Roholm (1939) and Fritz (1958), chemical analysis of ash from a rib yielded a value of 1 15 per cent fluorine The second case (F 2) was a 64 year old man who died from a brain tumour, diagnosed 4 weeks earlier and who had had 10½ years of fluorine exposure The roentgenographic examination showed stage I II fluorosis chemical analysis of ash from the iliac crest

Presented, in part, at the Fourth International Osteological Symposium, Sept 27–30 1972 in Prague Supported by Forschungsverband „Arbeitsmedizin" of the GDR

Table 1 Results of the static examinations and of the determination of microhardness in two fluorosis and three control skeletons

	Number of tests	t test
Lumbar vertebral body		
fracture load/area		
C1 – 46.7 kp/cm²		
C2 – 25.8 kp/cm²		
C3 – 41.9 kp/cm²		
F1 – 124.0 kp/cm²		
Femur slices		
fracture load/area		
C – 13.6 ± 1.9 kp/mm²	10	
F1 – 14.0 ± 1.6 kp/mm²	5	–
F2 – 16.4 ± 0.3 kp/mm²	3	$P_{C/F2} < 0.05$ $P_{F1/F2} < 0.05$
modulus of elasticity		
C – 780 ± 48.2 kp/mm²	10	
F1 – 610 ± 52.7 kp/mm²	5	$P_{C/F1} < 0.05$
F2 – 940 ± 41.7 kp/mm²	3	– $P_{F1/F2} < 0.01$
fracture load		
C – 6300 ± 1258 kp	10	–
F1 8400 to over 10 000 kp	5	$P_{C/F1} < 0.01$
F2 – 9000 to over 10 000 kp	3	$P_{C/F2} < 0.01$
Precisely defined cylinders from the femur corticalis		
fracture load/area		
C – 21.8 ± 1.05 kp/mm²	8	
F1 – 18.4 ± 0.88 kp/mm²	4	$P_{C/F1} < 0.01$
F2 – 22.3 ± 0.42 kp/mm²	4	– $P_{F1/F2} < 0.01$
modulus of elasticity		
C – 1607 ± 104 kp/mm²	8	
F1 – 1560 ± 46 kp/mm²	4	–
F2 – 1740 ± 89 kp/mm²	4	$P_{C/F2} < 0.05$ $P_{F1/F2} < 0.01$

Microhardness according to Vickers on the cross section of the femur 4 cm below the minor trochanter

Length of the diagonal of impression in arbitrary units (1 a.u. = 0.03 mm), the shorter this distance the harder the bone is

	Number of tests	t test
C1 – 2.02 ± 0.08 a.u.	71	
C2 – 2.04 ± 0.11 a.u.	85	
C3 – 2.02 ± 0.07 a.u.	66	
F1 1.98 ± 0.06 a.u.	121	$P_{C/F1} < 0.01$
F2 1.84 ± 0.08 a.u.	137	$P_{C/F2} < 0.01$ $P_{F1/F2} < 0.01$

C = control bones F1 = severe fluorosis F2 = moderate fluorosis

yielded a value of 0 74 per cent fluorine Three cases (C 1 to C 3) served as controls all 50 to 60 year-old men who died in traffic accidents

Examinations were made of the first lumbar vertebra, the neck of the femur, the distal third of the femur, three to five bone samples of the femur, sawn horizontally at a position 2 cm from the proximal third of the femur, and four cylinders milled from the femur cortex, 20 mm long and 5 5 mm in diameter in each case

The preliminary treatment of all human bones took place under identical conditions the investigations being conducted in a dry state at a room temperature of 22° C

The determination of microhardness was carried out on the surface of a piece of the femur taken from 4 cm below the minor trochanter The bone samples were dried for 24 hours at 100° C before the determination of microhardness They were kept in an air tight container until the test time and polished by means of a roughened glass plate shortly before the examination Microhardness was measured with a load of 0 1 kp, from the outside to the inside, in four different radial directions In each of the femoral slabs 70 to 140 imprints were measured

For the determination of static strength, tests were performed on a machine for testing the performance of materials made by the firm "Zwick", type 1385 and for the determination of the microhardness the Vickers method was used —on a Hanemann microhardness tester Zeiss D 32

RESULTS

Examination of static strength

For the determination of resistance to compression of the 1st lumbar vertebra, each individual vertebra was compressed at a rate of 0 5 mm/min, and the required load, as related to the compression, registered The resistance to compression was calculated from the maximal load registered, where the load surface was that of the vertebral body, calculated as an ellipse F 1 was found to have a three-fold higher resistance to pressure per unit area as compared with the three control vertebra (Table 1), F 2 was not subjected to this test

The determination of the flexural strength of the neck of the femur was undertaken in accordance with the test arrangement shown in Figure 1 The force was applied to the middle of the neck of the femur by means of a round head The three control bones registered 380 460 kp, F 1 registered 800 kp and F 2 registered 400 kp The value of this test is rather limited because the surface of load application is poorly defined

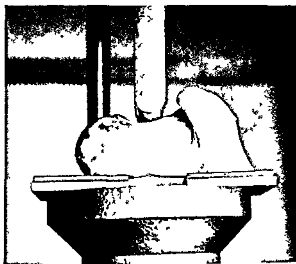


Figure 1 Experimental arrangement for testing of the flexural strength of the neck of the femur

For the determination of the flexural strength of the distal third of the femur, a 10 cm long piece of bone was removed from the lower section of the shaft of the femur, and tested for flexion in accordance with the layout of Figure 2 Here, no difference was found between fluorosis and control bones

The 2 cm thick slices from the femur were used for the determination of pressure strength and modulus of elasticity (Figure 3) As in the case of the vertebral compression test, the pressure resistance strength was determined from the maximal load per unit area of cortex The modulus of elasticity was calculated from the linear part of the load pressure curve

The pressure resistance value (fracture load/unit area) of the control pieces was 11 2 to 17 0 kp/mm² F 1 gave 12 to 15 6 kp/mm² and F 2 gave 16 to 16 6 kp/mm² Thus no definite difference between test and control bones was observed in this test

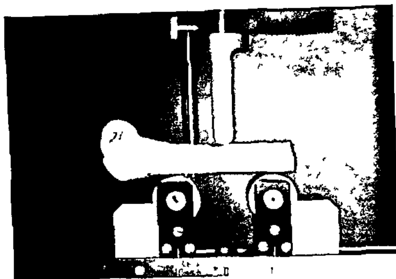


Figure 2 Experimental arrangement for the determination of the flexural strength of a 10 cm long piece of the distal femur

The modulus of elasticity of the control slices was 780 kp/mm², higher than in F 1 (610 kp/mm²), but lower than in F 2 (940 kp/mm²)

Whereas the control pieces were able to sustain an average load of only 6,300 kp, in both of the fluoride bones the highest load measurable by the machine was registered, viz 10,000 kp, without crushing some of the femur samples In the severe fluorosis (F 1) the crushing load was from 8,400 to over 10,000 kp and in the moderate fluorosis (F 2) from 9,000 to over 10,000 kp (Table 1)

The apparent contradiction between the absolute resistance to pressure and the breaking stress is resolved if one takes into consideration the difference in thickness of the cortex (Figure 4) of the severe fluorosis bone and control bones

The machined cortical bone cylinders (Figure 5) gave values for pressure resistance strength *(fracture load/unit area)* of 18 5 kp/mm² for F 1, which was lower than for the controls, (21 8 kp/mm²) and F 2 (22 3 kp/mm²)

The modulus of elasticity was 1607 kp/mm² in the controls, 1560 kp/mm² in F 1 and 1740 kp/mm² in F 2 (Table 1)

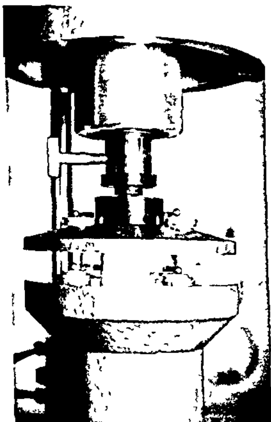


Figure 3 Experimental arrangement for the determination of the pressure strength of 2 cm thick femoral slices



Figure 4 Difference in corticalis thickness in severe fluorosis (on the left side) and two control bones

Determination of the microhardness

In severe fluorosis (F 1) there was an increase in hardness as compared with the control bones, while in moderate fluorosis (F 2) the increase in hardness was more pronounced (Table 1)

Summary of results

1 There was an increase of all parameters of bone strength in moderate fluorosis
2 There was an increase of the fracture load and fracture load/unit area of the vertebral body and of the femur slices, but a decrease of the modulus of elasticity of the femur slices and of the fracture load/unit area of the precisely defined cylinders from the femoral cortex in serious fluorosis (stage III)
3 There was a significant increase of the microhardness of the bones in moderate and serious fluorosis

DISCUSSION

Our data suggest that moderate fluorosis causes a real increase in bone strength, but that the compact part of the bone is statically of lesser value in severe fluorosis, as shown by the experiment with the isolated compact cylinders This inferiority can be explained by the irregular bone structure, the irregular mineralization, the osteoid, or the early development of bone porosity This defect is however counterbalanced by the enormous thickness of the compact part, and is even overcompensated, since in the whole bone abnormally high pressure force values were obtained The lack in quality is thus compensated for by the larger amount of bone In moderate fluorosis, all of the physico-technical parameters, including the microhardness, were higher than in the control bones

In spongy bone (vertebra, neck of the femur), even in severe fluorosis, there were higher values in the fluorosis bone Presumably, the greater static strength is due to the compact form of the spongiosa This and the increased microhardness results in bone that is harder than normal

The findings in animal fluorosis confirm the human results only as regards microhardness In rats an increased mi-

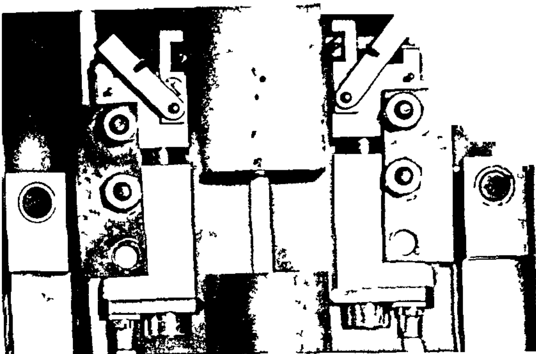


Figure 5 Experimental arrangement for the determination of pressure strength of milled cylinders from the femur corticalis

crohardness after fluoride feeding was found especially in young animals and at low and moderate doses (1 and 10 mg NaF/kg/day) In the experimental fluorosis of rats Franke et al (1972 a) did not find any definite changes as regards the static bone strength and neither did Saville (1967) or Naylor & Wilson (1967) However others have reported both increased (Rich & Feist 1970) and decreased (Gedalia et al 1964 Beary 1969 Wolinsky et al 1972) static strength in fluorotic bones of rats

In experiments on rabbits Jovanovits 1941) was able to detect a lowered modulus of elasticity after feeding fluoride in low doses and a lowered bending strength after high doses of fluorine Cristiani (1929) and Facchini (1969) achieved similar results (reduced bending strength of the tibia or reduced breaking strength of the femur) Bethke et al 1930) found a lower pressure resistance in the femur of fluorine fed piglets and Kick et al (1935) a lower breaking resistance in the femur of the pig The tests of Smith & Keiper (1965) of Henrikson et al (1970) of Krishna Rao et al (1973) and of Romanus (1974) yielded no significant modifications Phillips et al (1934) found an increase in the breaking force in the metatarsus in cows with fluorosis while Bell & Weir (1949) found a 25 per cent increased bending moment a slightly increased bend break force and a low modulus of elasticity in fluorine fed sheep

In the literature the authors found only a few reports about the relationship between fluorine content and hardness of bone In 1921 Forbes et al reported a lower microhardness in the bones of fluorine fed pigs Fujie (1961) found a reduced Vickers hardness on the incisors and mandibles of fluorotic cattle Most investigations reported are on teeth

however Boerma (1963) found in microhardness tests on whale teeth (these have a nearly 10-fold higher fluorine content than human teeth), just as Worner (1974) did on human dentine, no clear-cut correlation between the fluorine content and the microhardness Herrmann & Rozeik (1959) and Rozeik (1964) found in rats that the hardness of dentine and enamel decreased as the dose of fluorine administered was increased

In human fluorosis Roholm (1938) reported reduced elasticity while McGarrey & Ernstene (1947) described increased hardness In 1972 Evans & Wood investigated the ulnar cortex from a severe endemic human fluorosis They found a decrease of mechanical properties in tensile strength and an increase in compressive stress, while the modulus of elasticity was reduced in both tests These results correspond to ours in the case of severe fluorosis

The reasons for the different findings in animals and humans are to be found firstly in the difficulties encountered in determining some parameters, for example the fracture area, exactly, using the small rat femora Secondly the rat seems to be not a very suitable experimental object for studying bone fluorosis The histological and roentgenological changes in rats are indeed very slight in spite of fluoride feeding over 1 year and fluorine values in the bone ash up to 1 per cent (Franke et al 1972 a)

By contrast, sheep and cattle are extremely sensitive to fluorine In these animals excessive irregular periostal bone appositions and marked osteomalacic changes are often found (Shupe et al 1963)

On the basis of the investigations presented here we feel justified in supporting fluoride therapy in human osteoporosis At least in stage I II fluorosis the physicotechnical parameters were more favourable than for the control bones, and even in stage III fluorosis the vertebra showed a three-fold higher resistance to pressure than the control vertebra

Thus, bone formed under the influence of high doses of fluorine shows a certain static deterioration but this defect is compensated by larger amounts of bone and, for this reason, is still more resistant to stress than an untreated bone

ACKNOWLEDGEMENT

We are most grateful to J Jowsey D Phil Director, Orthopaedic Research Mayo Clinic Rochester, Minnesota USA, and Prof G Bauer Director of the Department of Orthopedic Surgery, University of Lund Sweden for their advice and helpful criticism of the manuscript

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Acta orthop scand 47 28 35 1976

POSTOPERATIVE WOUND INFECTION AFTER IMPLANT AND REMOVAL OF OSTEOSYNTHETIC MATERIAL

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Osteosynthetic material was implanted and removed in 972 consecutive operations in the upper and lower extremity Early post operative wound infection developed significantly more often after osteosynthesis than after removal of the implant, neither sex nor age influenced significantly the frequency of wound infection The latter was higher when insertion or removal of material was performed in the lower extremity than in the upper extremity The hip and ankle regions were involved most often *Staph aureus* and *Staph albus* predominated among the Gram positive infections gram negative infections however, occurred remarkably frequently *E coli* being the most common organism isolated To decimate exogenous and endogenous contamination of the wounds during operation aseptic and antiseptic measures should be reinforced In operation in a region proven to carry a higher post operative infectious risk i e the hip and ankle it is suggested that antibiotics should be administered at the time of osteosynthesis

Key words surgical wound infection orthopaedic fixation devices wound infection

Accepted 7 vii 75

The frequency of postoperative wound infection following orthopaedic operations ranges from 0 5 to 4 7 per cent (Tachdjian & Compere 1957, Raf 1964, Stevens 1964, Derian & Green 1966, Plaue & Hinz 1971, Charnley 1972 Lidgren & Lindberg 1974) In particular, post-operative wound infection is a serious complication following operations involving implantation of osteosynthetic material It is a matter of controversy whether osteosynthesis in different anatomical regions implies a difference in risk of postoperative wound infection (Raf 1964, Stevens 1964, Roles 1971, Lidgren & Lindberg 1974) The present study was undertaken to determine the influence of the actual operation site following insertion and removal of osteosynthetic material

MATERIAL AND METHODS

The investigation was retrospective and comprised 972 elective and acute operations on the extremities (703 implants and 269 removals of metallic osteosynthetic material) performed consecutively during the period 1963 1970 The distribution of patients according to age and sex

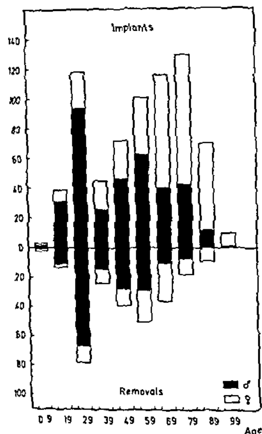


Figure 1 Age and sex of 972 patients with implant and removal of osteosynthetic material in the upper and lower extremity (1963–1970)

is shown in Figure 1 A patient was considered to have an early wound infection when clinical signs and symptoms of infection were present postoperatively before primary healing of the operation wound There was no routine bacteriological examination of infected wounds during the first years of the investigation

The preparation of the operation site consisted of washing with liquid soap for 3×3 min followed by propyl alcohol 35 per cent and iodine 2 per cent in ethyl alcohol 70 per cent, applied twice The patient was draped with sterile cotton towels and there was increasing use of a transparent, adhesive skin drape of plastic (Steri Drape®) throughout the period The operation wounds were sutured with resorbable material, except for the use of nylon stitches in the skin The administration of antibiotics was according to the judgment of the surgeon in question

Statistical methods

All data were processed in a computer and clinically relevant comparisons were made by distribution free statistical tests of significance (Siegel 1956)

RESULTS

The patient distribution (Figure 1) shows maxima in the 3rd and the 8th decades for implants and in the 3rd and the 6th decades for removals Young men had osteosynthetic material inserted and removed (for fractures of the upper ex-

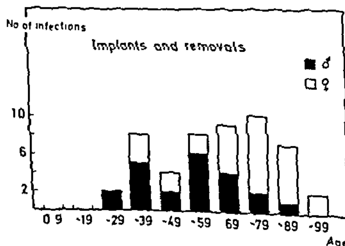


Figure 2 Fifty postoperative wound infections after implant and removal of osteosynthetic material in 972 patients

Acta orthop scand 47, 28–35, 1976

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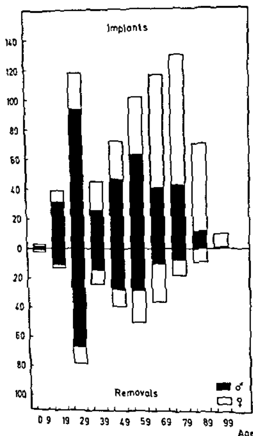


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RESULTS

The patient distribution (Figure 1) shows maxima in the 3rd and the 8th decades for implants and in the 3rd and the 6th decades for removals Young men had osteosynthetic material inserted and removed (for fractures of the upper ex

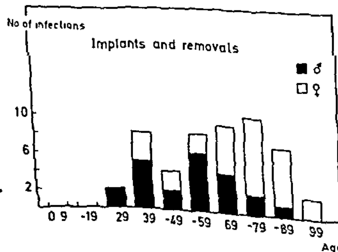


Figure 2 Fifty postoperative wound infections after implant and removal of osteosynthetic material in 972 patients

Table 1 Postoperative wound infection after insertion and removal of osteosynthetic material for fractures of the extremities

Osteosynthetic site	Implants	Infections		Removals	Infections	
Upper extremity	98	3	3 1 %	49	0	0 0 %
Lower extremity	605	40	6 6 %	220	7	3 2 %
Total	703	43	6 1 %	269	7	2 6 %

tremity, leg and ankle relatively more often than young women, while older women were operated on (hip operations) more often than older men; the removal of inserted material decreased rapidly with increasing age Fifty postoperative wound infections followed 972 operations (Figure 2), and the over-all incidence of infection was 5 1 per cent A Kolmogorov-Smirnov test between the two sample distributions (Figures 1 and 2) showed random variations ($P > 0\,05$) The ratio between men and women did not differ more than accounted for by chance, the infections after implants being for men 19 in 342 and for women 24 in 318, $P > 0\,05$ (Fisher's exact method)

Topographical analysis of postoperative wound infection

The total frequency of wound infection was significantly higher after osteosynthesis than after removal of the implant ($P < 0\,05$) (Table 1), this was also the case for the lower extremity The infection rate was higher in the lower extremity than in the upper, both for implants and removals, but the differences were not significant ($P > 0\,05$) Figure 3 shows the wound infection rates following insertion and removal of osteosynthetic material in 13 regions of the upper and lower extremities The differences between the frequencies of infection in the hip, thigh, knee, leg and ankle after osteosynthesis were not significant, nor was this the case if a single region was

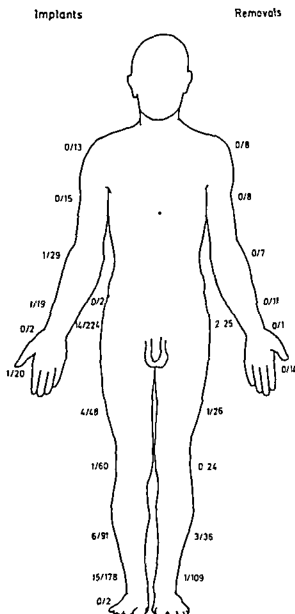


Figure 3 The frequencies of early postoperative wound infection after implants (left) and removals (right) of osteosynthetic material in 13 regions of the upper and lower extremity

Table 2 Postoperative wound infection after osteosynthesis in the hip region

Implant	No infection	Infection
Smith Petersen hip nail	44	1
Moore hip prosthesis	46	9
McLaughlin plate	100	4
Total	190	14

Table 3 Postoperative wound infection after insertion of osteosynthetic material for fracture of the ankle

Implant	No infection	Infection
Cerclage	96	10
Wiberg staple	86	9
Palmer pin	83	10
Rush pin	11	2
Agerholm staple	7	1
Screws	11	1
Others	20	5
Total	314	38

compared with the pooling of the other regions ($P > 0.05$) Osteosynthesis of the ankle was followed by infection significantly more often (12 in 45) than was the case with a pooling of the other inferior extremity sites (16 in 226), ($P < 0.01$), when sub-grouped according to the use of antibiotics

The different techniques of osteosynthesis in relation to the occurrence of wound infection are shown in Tables 2 and 3, where in some cases two or more implants have been inserted in the same operation wound Insertion of a Moore prosthesis was associated with postoperative wound infection significantly more often than after other treatment (chi square analysis $P < 0.01$) (Table 2) The number of infections was notably high after insertion of metallic implants for ankle fractures (Table 3) No statistically significant differences were found (for the proportion of cases of wound infection to the total of osteosynthetic implants) between fractures of the femoral neck, the trochanter region, the femur shaft, the leg or the ankle

Bacteriology

Gram positive bacteria dominated, especially *Staphylococcus aureus* (coagulase positive) (Table 4), but the Gram-negative *Escherichia coli*, *Proteus* spp and *Pseudomonas aeruginosa* were also isolated from infected *hip and ankle* wounds Only Gram positive bacteria were identified from infections following

Table 4 Organisms in 50 postoperative wound infections after implant and removal of osteosynthetic material in 972 patients Removal in brackets

	Staph aureus	*Staph albus*	*a streptococcus*	Gram neg organism	No growth	No report
Upper extremity						
Elbow	1					
Forearm	1					
Hand				1		2
Lower extremity						
Hip	7 (1)	(1)	2	6	1	
Thigh	3 (1)					1
Knee						1
Leg	3	1				1
Ankle	2	1			1 (1)	4 (2)
				5	3	6
Total	17 (2)	2 (1)	2	12	5 (1)	14 (3)

Table 1 Postoperative wound infection after insertion and removal of osteosynthetic material for fractures of the extremities

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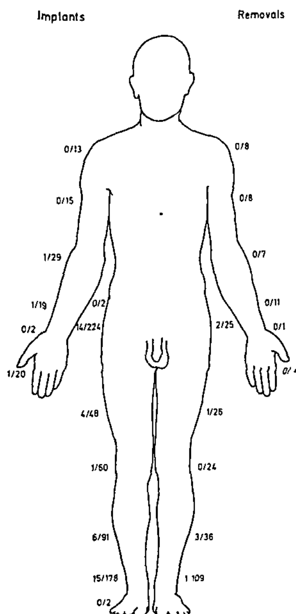


Figure 3 The frequencies of early postoperative wound infection after implants (left) and removals (right) of osteosynthetic material in 13 regions of the upper and lower extremity

tensive exposure and repetitive manipulations. Earlier, the hip was shown to be a region of high risk (Tachdjian & Compere 1957, Raf 1964, Salvati & Wilson 1973, Lidgren & Lindberg 1974).

Bacterial species

Staph. aureus and *Staph. albus* were responsible for most of the Gram positive infections after osteosynthesis and for all infections after removal. The relatively frequent isolation of Gram negative species from hip and ankle infections was remarkable compared to the findings of others (Tachdjian & Compere 1957, Fogelberg et al. 1970, Boles 1971, Fitzgerald et al. 1973). The presence of bacteria is one out of five major contributory factors in the development of wound sepsis (Davidson et al. 1971), and quantitative and qualitative bacteriological evidence has recently shown that wounds are contaminated during operation to various degrees from exogenous and endogenous sources (Lilly et al. 1970, Fitzgerald et al. 1973, Raahave 1974 a). In this study the isolation of Gram negative bacteria and the sensitivity patterns of *Staph. aureus* indicate the patients' own indigenous biota as the source, keeping in mind the nearness of urethra and anus to operation wounds of the lower extremity. Analogously, Gram negative infections dominated in the groin after vascular operations (Shaw et al. 1973). Apart from this endogenous source the wound may be contaminated during operation by mainly Gram positive bacteria from the environment with gloves, instruments and air as vectors (Raahave 1974 a).

The bacterial contamination of the operation wound should be reduced to a level which can be overcome by the natural host defences. In this study disinfection of the operation site relied on iodine in alcohol. Chlorhexidine, however, is as powerful as iodine and is without irritant and sensitizing effects. This disinfectant is much in use at present (Lowbury & Lilly 1973), and was recently shown to eradicate aerobic and anaerobic skin flora almost completely (Raahave 1973, Lykkegaard Nielsen et al. 1975).

Aseptic barriers, including the use of a sterile enclosure (Charnley 1964, 1972), are established between the sterile zone and other areas which harbor bacteria in the operating room. By this means the bacteria from the skin and mucous membranes of the room personnel should be denied access to the wound. The use of plastic skin drapes has been advocated as a further aid, but these drapes neither reduced the number of bacteria (Lilly et al. 1970, Raahave 1974 b) nor the frequency of wound infection (Paskin & Lerner 1969, Jackson et al. 1971).

Antibiotics

Approximately one third of the patients in this retrospective study received antibiotics on the basis of apparent need, not on an alternate basis. The striking feature was a significantly higher frequency of wound infections after lower extremity osteosynthesis when the patients were given antibiotics postoperatively. This is in line with earlier retrospective studies (Tachdjian & Compere 1957, Derian & Green 1966), but is also seen in prospective investigations (Sanchez-Ubeda et al. 1958, Scales et al. 1972). Preventive antibiotic treatment, however, should not be abandoned, but timed correctly in relation to the operation, i.e. per- and preoperatively (Eftekhar 1973, Ruedy 1973); adequate concentrations of antibiotics could then be built up in the wound tissue (Raahave 1975 b) to combat bacterial contamination at the moment it occurs (Burke 1961). This has been confirmed in recent clinical trials of hip surgery (Fogelberg et al. 1970, Boyd et al. 1973, Ericsson et

removal of osteosynthetic material The cultures were obtained by the cotton swab method, which may explain the apparent paradox of 'no growth" in association with clinical wound infection, because this sampling method does not reveal the full extent of colonization, being qualitative, not quantitative (Raahave 1975 a) One-third of the *Staph aureus* strains identified were fully sensitive to penicillin and one-fifth were resistant

Antibiotics

Penicillin (68 4 per cent), alone or in combination with streptomycin or other antibiotics (26 3 per cent), was administered to 37 6 per cent of the patients The treatment was most often initiated in connection with osteosynthesis or removal from the lower extremity (Table 5), and postoperative wound infection developed significantly more often in patients treated with antibiotics than in those who were not so treated ($P < 0\ 05$)

DISCUSSION

Topography of postoperative wound infection

Osteosynthesis in the extremities was followed by postoperative wound infection significantly more often than was removal of the implant The infection rate was higher when both procedures were carried out in the lower than in the upper extremity, though not significantly so There does not appear to be any comparable study in which early postoperatively wound infection has been assessed following insertion and removal of osteosynthetic material

Frequencies of 3 1 to 12 0 per cent have been reported after osteosynthesis and endoprosthetic implants (Tachdjian & Compere 1957, Raf 1964, Boyd et al 1973, Salvati & Wilson 1973, Kavlie & Sundal 1974, Lidgren & Lindberg 1974), while a frequency of wound infection following osteosynthesis of 12 7 per cent was found in a general surgical department (Jepsen 1973) Following total hip replacements, an incidence rate as low as 0 5 to 2 per cent has been reported, including late manifestations (Charnley 1964, 1972) In the present study both sexes seemed equally prone to postoperative wound infection, a finding in line with that of Stevens (1964), and age in itself had no influence, two factors which others have stated to be of some importance (Raf 1964, Davidson et al 1971, Lidgren & Lindberg 1974)

The frequency of wound infection in osteosynthesis and removal varied from region to region, being highest after osteosynthesis in the ankle region A further sub grouping according to the type of implant showed that the insertion of a Wiberg staple, a Palmer pin and a cerclage were associated with infection of wounds to a uniform degree These implants were often used together in the same operation and the inference is that the aseptic technique may have been broken by manoeuvres necessary for reposition of the fracture and fitting the implants Such breaks may have also occurred after osteosynthesis in the hip region, and especially when a Moore prosthesis was inserted, demanding ex-

Table 5 Administration of antibiotics and postoperative wound infection after insertion/removal of osteosynthetic material in the extremities

	No infection Antibiotics		Infection Antibiotics	
	+	—	+	-
Implants				
Upper extremity	42	53	2	1
Lower extremity	271	294	28	12
Removals				
Upper extremity	1	48	0	0
Lower extremity	19	194	2	5
Total	333	589	32	18

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al 1973) When administered intravenously, antibiotics might also counteract episodes of bacteriaemia from infectious foci, thus preventing bacterial inoculation into the operation wound by the haematogenous route In the case of bloodless osteosynthesis in the extremities, sufficient amounts of antibiotics should be given in time to ensure an adequate level in the operation wound, since no further antibiotic would be carried to the wound at the time of operation

This study suggests a need for preventive treatment with antibiotics at the time of osteosynthesis in the lower extremity, in particular the hip and ankle whereas this seems unnecessary for osteosynthesis or removal in the upper extremity

ACKNOWLEDGEMENTS

The investigation was supported in part by research grants from the National Research Council for the Medical Sciences and from the Legacy of Carl and Ellen Herz

I wish to thank J Nyboe and U Grolin Office of Statistics, Rigshospitalet for their help in computing data and statistical assessments

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the finger joints in slight flexion After 4 weeks immobilization the cast is cut and all the sutures including the pull-out wire are removed and active exercise is initiated

RESULTS

Fifteen fingers in 14 patients have been treated with this method since 1970 Table 1 summarizes the data on the patients Thirteen were male and only one was female Their ages ranged from 17 to 39 years

Seven fingers had had unsuccessful tendon surgery previously, and the others had extensive scars from poor initial treatments

The results of the operation were assessed on the basis of bow stringing fingertip to palm distance and loss of extension as shown in Table 2 The results of 12 out of 15 fingers were unsatisfactory Unfortunately there was no definite proof that our attempted idea had anything to do with the tendon not adhering and not bow stringing

DISCUSSION

The purpose of our method were 1 prevention of adhesion and 2 substitution of the pulley mechanism by suturing

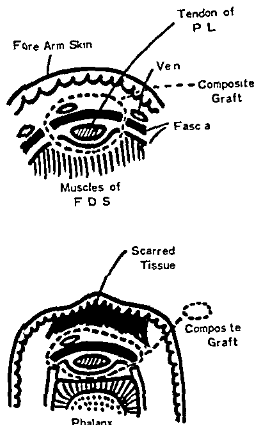


Figure 1 Transverse section of the forearm and the finger



Figure 2 Skin incisions

Acta orthop scand 47, 36–40, 1976

FREE GRAFT OF FASCIAL TUBE IN FLEXOR TENDON REPAIR IN THE DIGITAL SHEATH OF THE HAND

An Attempt at a Composite Tissue Autograft

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Various reconstructive methods have been reported for cicatricial tendon beds Since 1970, when the flexor tendon gliding mechanism of the finger has been damaged in the area of "no man s land and conditions are less than optimal for conventional tendon grafting, the authors have attempted to graft a fascial tube including tendon and paratenon of the palmaris longus The technique is described and the results reported

Key words free graft, fascial tube, flexor tendon repair, no man s land, hand, composite tissue autograft

Accepted 21 ix 75

The results of free tendon grafting for the division of flexor tendons in the *so-called no man's land are not always* satisfactory (Suzuki 1971) This is especially true when the preoperative condition of the fingers is poor due to extensive scarring from poor initial treatment Many studies have reported preventing adhesion of the free tendon graft The authors have tried to replace the defective skin with a pedicle skin graft and have also investigated the use of millipore membranes and silicon rods The purpose of this paper is to report our clinical experience with the use of palmaris longus tendon wrapped with the adjacent fasciae (Boyes 1964, Suzuki 1973) in an attempt to provide a favorable tissue environment for the grafted tendon (Figure 1)

METHOD

Incisions are made as shown in Figure 2 In order not to expose the palmaris longus tendon free in the air, fine nylon sutures are loosely placed at each side of the tendon as shown in Figure 3 Then the fascial tube of the necessary length is removed with the paratenon and the tendon, as shown in Figure 4

In the recipient finger the divided tendons and the damaged sheath are resected completely If the digital sheath is intact, this sheath is preserved as much as possible *When the digital* sheath is absent, the edge of the grafted fascia is sutured to the remnant of the digital sheath at both sides The distal end of the tendon is sutured to the distal phalanx with a pull out wire technique and the proximal end is usually sutured to the profondus tendon with criss-cross wire sutures *When the retinacular liga*ment can be approximated it is sutured with nylon and the skin is closed with interrupted sutures After careful dressing a plaster cast is applied with the wrist in moderate flexion and

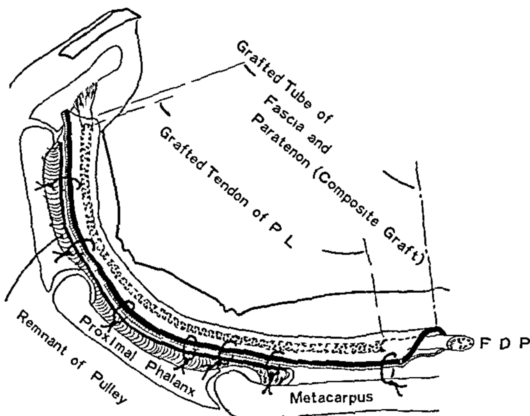


Figure 4 Grafted fascial tube

the fascia to the base (Peacock 1960, Cameron et al 1970) The postoperative results suggested that adhesion might have been prevented to some extent, but the presence of bow stringing in the majority of the cases indicated that the pulley mechanism had not been satis factorily replaced by this technique And, the authors must admit, this technique would have a limited value in cases in which the scarring is not so extensive as to require the use of a silicon rod (Grais-

Table 3 Recommended procedures

Scar of the Soft Tissue Before Surgery	Pedicle Skin Graft	Recommended Procedure
Less	(−)	Usual Free Tendon Graft
Moderate		Composite Graft or Graft of Fascial Sheath
Severe	(+)	Silicon Rod

Table 1 Summary of 14 patients

Patient	Sex	Age	Finger	Injured by	Preoperative grade				Time from injury to reconstruction
					Scar	Nerve	Joint	Multiple	
1 05460 N S	M	19	R Index	Machine	+	—	—	—	5 months
2 05549 H A	M	22	R Mid & Ring	Machine	+	—	—	+	6 months
3 10703 S K	M	25	L Index	Glass	+	—	—	—	4 months
4 12534 K M	M	28	L Index	Chisel	+	—	—	—	4 months
5 16652 K I	M	27	R Ring	Glass	+	+	—	—	1 month
6 16455 H T	M	23	L Mid	Glass	+	+	—	—	7 months
7 20256 T N	M	20	L Ring	Rotating saw	+	+	—	+	5 months
8 26259 Y O	*M*	*17*	*R Mid*	*Rotating saw*	+	+	+	—	*4 months*
9 30104 T S	M	38	R Ring	Machine	+	—	—	—	1 month
10 30884 H H	F	39	L Index	Rotating saw	+	+	+	+	2 months
11 32460 A T	M	25	R Ring	Door	+	—	—	+	3 weeks
12 33462 M S	M	30	R Mid	Knife	+	—	—	+	2 months
13 33573 A O	M	33	L Ring	Machine	+	+	—	—	4 months
14 36307 M N	M	20	L Index	Steel	+	+	—	—	2 months

Table 2 Results of follow up (8 to 36 months, average 20 months)

Patient	Finger	Pulley defect in			Bow string at		Distance of pulp from distal P C	Loss of extension (in degrees)
		Meta carpal	P phal	M phal	M P J	P I P J		
N S	R Index	—	+	+	+	+	6 0 cm	39
H A	R Mid	—	+	—	+	—	2 9 cm	76
	& Ring	—	+	+	+	—	3 2 cm	82
S K	L Index	—	+	—	+	—	2 6 cm	44
K M	L Index	+	—	—	—	+	2 0 cm	56
H T	L Mid	—	+	+	—	+	5 5 cm	75
T N	L Ring	—	—	+	+	+	2 8 cm	32
Y O	R Mid	—	—	+	+	+	3 0 cm	30
T S	R Ring	—	—	+	—	+	2 8 cm	44
H H	L Index	+	—	—	—	—	5 6 cm	36
A T	R Ring	—	—	—	—	—	4 5 cm	46
A O	L Ring	—	—	+	—	+	1 9 cm	18

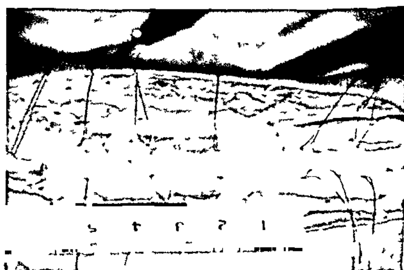


Figure 3 Sutured fasciae at each side of the palmaris longus tendon

Acta orth p scand 47 41–45 1976

PERIPHERAL NERVE INJURIES OF THE UPPER EXTREMITY

Sensory Return of 137 Neurorrhaphies

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The results of sensory recovery of 137 neurorrhaphies of the upper extremity in 96 patients are reviewed There were 85 primary and 52 secondary repairs Various factors influencing the results and an evaluation based on the 2 point discrimination test are presented Secondary repair within 3 months in the hand area gives better results than primary repair

Key words nerve injuries, neurorrhaphies nerve repair, primary/secondary, two point discrimination

Accepted 11 x 75

There are several procedures for evaluating sensory nerve recovery after nerve division, but there is still a lack of objective methods In most of the tests we have to rely on the co-operation and power of concentration of the patient Tests for the modalities of temperature, pain and touch do not reveal the whole truth Even though these modalities appear satisfactory the hand may still function poorly Tests for the functional value of sensibility—tactile gnosis—are therefore more [illegible] consid[illegible] test ([illegible] grading tactile gnosis and expressing the results numerically (Stromberg et al 1961, Moberg 1962, Önne 1962, v Prince & Butler 1967) In addition, there are other interesting ancillary examinations in existence such as vibration sensograms (McQuillan 1970)

The question of primary or secondary nerve repair is still controversial The main purpose of the present study was to compare the results of *primary* and secondary nerve repair and to investigate the influence of age, delay in repair and other factors

MATERIAL

The series consists of 96 patients with 137 neurorrhaphies in the upper extremity treated at the Department of Orthopaedics and Traumatology, University Central Hospital Helsinki from *1960–1969* (Kanpaanpaa & Bakalim 1973) During this time the operating microscope was not available at this hospital For this reason no funicular transplants were done There were 28 females and 68 males in the series The age and sex distribution can be seen in Figure 1 The follow up varied from 1–10 years (mean 4 years 11 months) The minimum follow up was 1 year (3 patients) Nerve lesions caused by glass or a knife were the most common occurring in 55 patients Seven patients had attempted *suicide* A ragged wound in association with the nerve lesion was treated in 33 cases (circular saw, compression in machine explosion bullet wound etc) The proportion of ragged wounds was

ford et al 1969, Hunter et al 1969, Hunter & Salisbury 1971), but not optimal enough to do a conventional free tendon grafting (Goldner & Coonrad 1969, Boyes & Stark 1971) With further improvement of the technique the authors hope that the results will be more favorable and that the pulley mechanism can be substantially preserved (Barton 1970) or otherwise reconstructed (Table 3)

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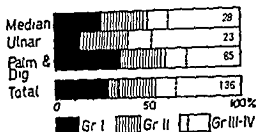


Figure 4 Results in the various nerves

A neuroma was noted in 6 out of 29 patients with median or ulnar nerve lesions A neuroma was present in the 2 PD grade I in three cases, grade II in two cases and grade III in one case

The results seem to be influenced by the different degrees of training of the surgeons involved There were three surgeons who specialized mainly in hand surgery, 10 general orthopaedists and several registrars operating during the years 1960 1969 Seventy-two neurorrhaphies were done by registrars, 28 by general orthopaedists and 37 by hand surgeons The registrars had 18 per cent good results (2 PD grade I) and the more trained groups 37 and 39 per cent, respectively Regarding the poorest grade (2-PD IV) the results are reversed Registrars 47 per cent, orthopaedists and hand surgeons 29 and 26 per cent, respectively

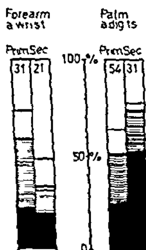


Figure 5 Results of primary and secondary suture of wrist / forearm nerves compared with those of the palm and digits

The clinical material was divided into age intervals of 10 years (Figure 3) Seven nerve repairs were done in four children aged from 7 to 10 years The two-point discrimination test was done with care and patience and it can be regarded as reliable All of them had good sensory recovery In the two older groups 16–17 per cent obtained good results (2-PD grade I)

Median and ulnar nerve lesions were mainly in the region of the wrist (42/51) the remainder being in the forearm and arm (5/51 and 4/51) The percentage of grade I repairs was as follows median 25 per cent, ulnar 13 per cent, palmar-digital 34 per cent (Figure 4)

The results of primary and secondary nerve repairs were compared Considering all the repairs, grade I results were achieved in 21 per cent of the 85 primary repairs and 38 per cent of the 52 secondary repairs In the palmar digital group, satisfactory results were found in 24 per cent of 54 primary repairs, compared with 52 per cent of 31 secondary repairs In the group wrist-forearm arm, grade I results were recorded in 22 per cent of 27 primary repairs and 19 per cent of 21 secondary repairs (Figure 5)

When the suturing was performed within 24 hours of the injury it was considered to be primary The secondary repairs were divided into the following groups 0–1, 2 3, 4 6, and 7 9 months Forty nine of the 52 secondary sutures were done within 9 months The remaining three were repaired after 12 months Figure 6 illustrates the results of primary repair (left side of the histogram) and the variation in results with time in cases of secondary repair (right side of the histogram) The most suitable time for secondary suture seems to be between 1 and 3 months

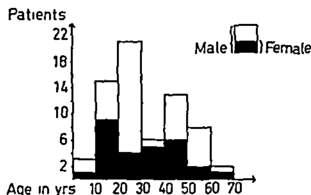


Figure 1 Age and sex distribution of the 96 patients

higher in the area of the hand and fingers (42 per cent) than in the wrist region (24 per cent) Included were 28 injuries to the median nerve, 23 to the ulnar nerve, one to the superficial radial nerve and 85 to the palmar and digital nerves Primary repair of the nerve was performed in 85 instances and secondary repair in 52

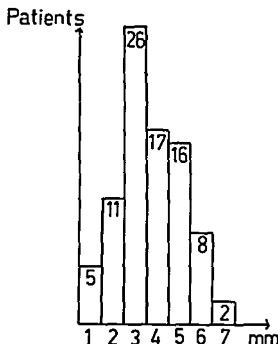


Figure 2 Distribution of the 2-point discrimination values in the uninjured hand of 85 patients Mean 3 7 mm

RESULTS

Ninety-six patients were interviewed and examined by the authors The appearance of the hand was noted, particular attention being paid to the presence of neuromas of the median and ulnar nerves The Ninhydrin test, light touch (cotton wool), pinprick and two point discrimination tests were performed The uninjured hand was also examined using the 2-PD-method Grading of 2-PD values was done as illustrated in Table 1 This was based on the examination of the fingertips on the control hand (Figure 2) These values can be considered normal and 98 per cent of the patients had a 2-PD ranging between 1 and 6 mm (the poorest finger on the control hand)

Of the 96 patients, nine had some diminished staining of the fingerprints with Ninhydrin, compared with the control fingers Seven of these belonged to the 2-PD grades III–IV and two to the grades I II The remaining 87 patients had a normal Ninhydrin test Skin atrophy was found on the injured fingers of 20 patients Atrophy was distributed equally between the four 2-PD grades

Table 1 Grouping of the results according to the different 2 point discrimination (2 PD) values

Group	2 PD
I	≦ 6 mm
II	7–15 mm
III	16–20 mm
IV	> 20 mm

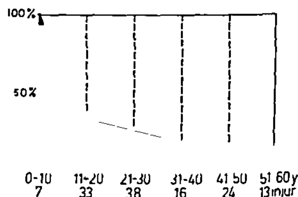


Figure 3 Percentage of 2 PD grade I (≦ 6 mm) in the various age groups

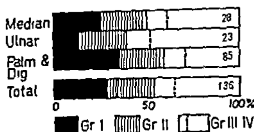


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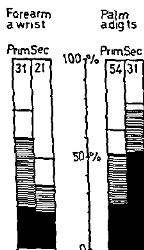


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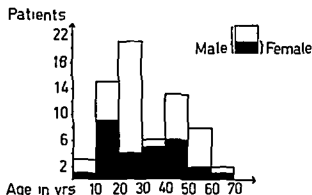


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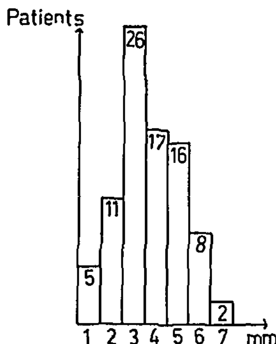


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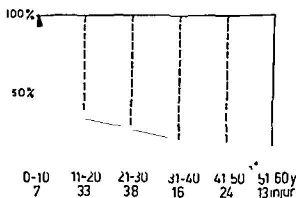


Figure 3 Percentage of 2 PD grade I (≦ 6 mm) in the various age groups

neural damage The results of the present investigation support the concept of secondary nerve repair especially in lesions of the hand region and under conditions similar to those described in this hospital during the years 1960–1969

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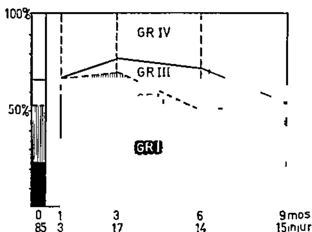


Figure 6 The effect of suture delay on the results, evaluated by the 2 point discrimination test O = primary suture

DISCUSSION

Three to five millimeters have been considered to be the normal 2-PD values for adults (Stromberg et al 1961, Onne 1962, v Prince & Butter 1967) The present examination of uninjured fingertips gave approximately the same result (Figure 2) Stromberg et al (1961) and Sakellarides (1962) believe that maximum recovery cannot be expected until 2 years have elapsed from the time of injury

The Ninhydrin test was developed by Moberg (1958, 1968) and its use was encouraged by, for example, Flynn & Flynn (1962) Since then there have been many authors who do not consider that the return of sudomotor function occurs *peripessu* with sensory return (Stromberg et al 1961, Moberg 1962, Simon & Mann 1966) The Ninhydrin test was found to be positive within 5 7 months after injury In the present study we found staining of the fingerprints in 87 of the 96 patients The test becomes positive before full sensory recovery takes place

The operating microscope was not available for these nerve repairs Usually some other form of magnification (magnifying glasses etc) was used Hand surgeons performed their neurorrhaphies in the daytime in undisturbed circumstances and most of their repairs were secondary This, in addition to their experience, may well explain the differences in results

It is well known that children and young adults achieve the best results after nerve repairs This has been reported by many authors (Stromberg et al 1961, Sakellarides 1962, Onne 1962, Brown & Brown 1967) and was found also in the present study Children seem to possess unknown factors which improve their recovery

Seddon (1949, 1957) and Brown & Brown (1967) have supported the idea of secondary neurorrhaphy because suturing is technically easier in the thickened epineurium and it is easier to judge the extent of the damage and the infection risk is less Sakellarides (1962), Onne (1962) and Hagen (1970) advise primary repair if conditions are ideal (cleanly divided nerve, skilful operating team etc) In this study of nerve injuries to the upper extremity, secondary repairs gave better results When the injuries were divided into palmar-digital area and forearm-wrist-arm area the former had better results when repaired secondarily but with the latter there was no marked difference between the results of secondary and primary repair Most of the secondary repairs were done by general orthopaedists and hand surgeons Another reason is also that the hand-finger area had a higher incidence of ragged wounds (42 per cent) compared with the wrist-forearm area (24 per cent)

Views diverge regarding the timing of secondary nerve repair Brown & Brown (1967) support the opinion that the longer the delay the greater the chances of irreversible changes in the distal end of the nerve The most suitable time would be within the first 6 months (Onne 1962, Sakellarides 1962) following injury According to Seletz (1966) at 3–6 weeks it is possible to see the total limits of the central neuroma and the extent of the

Table 1 Age and sex distribution of the patients

Age (years)	Males	Females	Total
0–9	–	1	1
10–19	–	–	–
20–29	–	–	–
30–39	–	–	–
40–49	4	1	5
50–59	–	4	4
60–69	7	1	8
70–79	1	1	2
80–	–	–	–
All ages	12	8	20

Table 2 Number of patients by anatomical site of the tumour and sex in a series of 20 cases of chordoma

Anatomical site	Males	Females	Total
Sacral	10	5	15 (75 %)
Vertebral	1	2	3 (15 %)
Spheno-occipital	1	1	2 (10 %)
Total	12	8	20 (100 %)

History and symptoms

Sacral chordomas Six patients (40 per cent) gave a history of trauma in the region of the subsequent tumour The period of time between the trauma and the diagnosis of chordoma varied from one month to 7 years (median 4 years)

Eleven patients (73 per cent) complained of pain, this being the most common symptom (Table 3) A tumour like growth in the sacral region, alone or accompanied by pain had been noticed by nine patients (60 per cent), in two patients the tumour had induced urinary incontinence

In eight instances, the first diagnosis was incorrect sciatic syndrome (3), dermoid cyst (4) or prostatic hyperplasia (1) One patient had been subjected to an operation for disc prolapse before the institution of a correct diagnosis of chordoma

Table 3 Presenting symptoms in a series of 20 patients with chordoma

Symptom	Sacral N = 15	Vertebral N = 3	Cranial N = 2
Pain	11	2	–
Abnormal growth	9	–	–
Urinary incontinence	2	–	–
Fever	–	1	–
Tetraparesis	–	1	–
Visual impairment	–	–	2
Medullary compression	–	–	2

Vertebral chordomas The patient with a thoracic tumour had a history of pain and fever (Table 3), a tumour was palpable on the left side, and initially a false diagnosis of renal abscess was made Progressive pain experienced in swallowing was the symptom of one of the patients with a cervical tumour The other, who gave a history of neck distension like trauma one year earlier was suffering from progressive tetraparesis (Table 3)

Spheno occipital chordomas Both tumours had induced visual impairment, along with various neurological symptoms (Table 3)

Duration of symptoms Wide variation was apparent in the duration of the symptoms < 3 months in three cases, 3 6 months in eight cases, 6–12 months in seven cases, and more than 1 year (6 years) in one case, the median was 6 months and the mean 12 7 months

Findings

On first examination, 13 patients had a palpable tumour dorsally, in the gluteal or sacral region In eight instances, the tumour could also be found by rectal palpation A massive tumour was observed in the hypopharynx of one patient with a cervical chordoma

The destruction of bone, suggestive of a tumour, was observed at the first X ray examination in 11 patients (73 per cent) with a sacral tumour One of the cervical

Acta orthop scand 47, 46–51, 1976

CHORDOMA IN FINLAND

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During the period 1953–1971, 20 cases of chordoma were reported to the Finnish Cancer Registry Twelve of the patients were males The mean annual (crude) incidence of chordoma in Finland was 0 30/10^6 in males, and 0 18/10^6 in females Fifteen of the tumours were sacral, three vertebral, and two cranial Local recurrences were common, and distant metastases were observed in 60 per cent of the cases, this exceeds the proportion usually mentioned in the literature The commonest treatment was surgery combined with postoperative high dose irradiation The relative 5 year survival rate was 35 per cent, and the 10-year rate 18 per cent

Key words chordoma, bone tumours, histology, treatment, prognosis

Accepted 2 ix 75

Chordomas arise in the remains of the embryonic notochord These tumours are rare up to 1969, less than 700 cases had been published in the literature (Beaugie et al 1969) Rissanen & Holsti (1967) have reported seven cases of sacrococcygeal chordoma from Finland This paper concerns the 20 cases of chordoma reported to the Finnish Cancer Registry during the period 1953–1971

PATIENTS AND METHODS

During the period 1953–1971, the Finnish Cancer Registry received reports on 20 cases of chordoma The hospital records concerning the diagnostics and treatment of chordoma were compiled, and the patients were followed up until death or until June 30 1974 a complete follow up was achieved All tumours had been histologically verified In 19 instances, re exam ination of the sections (L T) confirmed the diagnosis of chordoma In one case, although neither tissue nor slides were obtained, the clinical findings, and the original statement of the pathologist made regarding a specimen taken at operation, were typical of a chordoma

RESULTS

Chordomas constituted 1 5 per cent of all the malignant bone tumours reported to the Finnish Cancer Registry during the period 1953–1971 The mean annual (crude) incidence of chordoma in Finland was 0 30/10^6 in males, and 0 18/10^6 in females

Twelve of the patients were males, eight were females (male/female ratio 1 5) Table 1 indicates the age distribution of the patients The mean age of the patients was 55 5 years The anatomical distribution of the tumours is given in Table 2

Table 5 Localization of the metastases in a series of 20 patients with chordoma

Localization of the metastases	Localization of the primary tumour Sacral N = 15	Vertebral N = 3	Spheno occipital N = 2	Total N = 20
Bone	8	–	–	8
Lungs	5	–	–	5
Liver	2	1	–	3
Lymph nodes	–	2	–	2
Skin	2			2
Chest wall	2	–	–	2
No metastases	6		2	8

the subject of radical operation, and one patient (cervical tumour) received radiotherapy alone no treatment was given in the case with a thoracic tumour (Table 4)

An operation was performed on one of the *spheno occipital* chordomas but the other remained untreated (Table 4)

Treatment by X ray or telecobalt, 3 000–8 200 rad, was administered both to the nine cases subjected to postoperative irradiation and to the three cases given radiotherapy only In one case, radiotherapy was supplemented by cyclophosphamide (6 000 mg)

The *treatment* of locally recurring sacral chordomas was as follows one case *operation only*, two cases operation supplemented with postoperative radiotherapy, two cases radiotherapy, and in three cases no treatment The radiation dose was 3 000 8 000 rad X ray or telecobalt Radiotherapy, alone or in combination with cytostatic agents (cyclophosphamide, 5 fluorouracil), was the mode of treatment applied at the metastatic stage of the disease

Clinical course

In 15 –
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the recurrence was < 1 year in three cases 1–3 years in eight cases, 3 6 years in three cases, and > 6 years in one sacral case (12 years)

Distant metastases were observed in 12 cases (60 per cent), in seven of them, several metastases were observed In three instances the metastases were studied histologically The commonest sites of metastases were bone lungs and liver (Table 5) The period of time from primary treatment to appearance of the metastases ranged from one month to nearly 20 years None of the metastases was present at the time of diagnosis

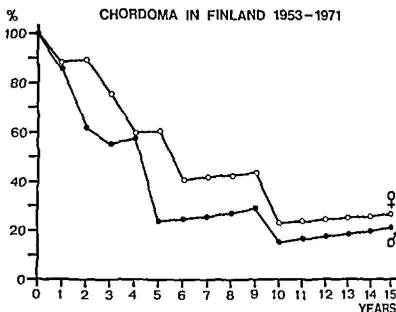
The 5 year relative survival rate of the patients was 35 per cent, and the 10 year rate 18 per cent (Figure 1) Three patients were alive at the end of the follow up period, only one of them was tumour-free

In one case, hypernephroma was diagnosed four years after a sacral chordoma Widespread metastases developed, and the patient died from her renal tumour, the chordoma remained local

DISCUSSION

The Finnish Cancer Registry covers the entire country It receives reports of cases of malignant neoplasms from hospitals pathological laboratories and practitioners Various check ups have indicated that the number of cases not reported to the Registry is negligible It

Figure 1 Relative survival curves (calculated by the actuarial method) of all cases of chordoma diagnosed in Finland during the period 1953–1971 (12 males 8 females)



tumours had induced destruction of the corpus C IV, visible on tomography

Histology

The first histological diagnosis was obtained from a biopsy specimen in eight cases, from an operation specimen in 11 cases, and at autopsy in one case In 18 cases, one or more tissue specimens from the primary tumour were available for histological study, in one case, the only specimen was from the recurrent tumour Sixteen chordomas were considered as "typical", taking the form of lobular tumours composed of loosely arranged cells, with rather pleomorphic nuclei, and often foamy cytoplasm mitoses were few Varying amounts of intercellular homogenous mucin-like material were discernible, together with necrosis

Three tumours exhibited atypical features The general structure of one of these tumours resembled adenocarcinoma but small areas, with typical chordomatous pattern, revealed the real nature of the tumour The two remaining tumours displayed mostly undifferentiated tissue with areas suggesting chordoma

Mode of treatment

Twelve of the 15 patients with *sacral* chordomas were initially subjected to operation, five of these operations were considered macroscopically radical Postoperative radiotherapy was instituted in nine cases (Table 4)

One of the three patients with *vertebral* tumours (located cervically) was

Table 4 Mode of treatment in a series of 20 patients with chordoma Figures in parentheses indicate postoperative radiotherapy

Localization of the tumour	No of patients	Radical operation	Palliative operation	Radiotherapy alone	No treatment
Sacral	15	5 (4)	7 (5)	2	1
Vertebral	3	1		1	1
Spheno occipital	2		1		1 *

* Diagnosed at autopsy

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can be concluded that the series of patients presented in this paper probably represents all of the cases of chordoma diagnosed in Finland during the period concerned, and accordingly that calculation of an incidence rate is justified

Incidence rates of chordoma have seldom been presented In Sweden, the mean annual incidence in 1958–1968 was 0 49/10⁶ (Larsson & Lorentzon 1974) The rate in Finland (0 30/10⁶ in males and 0 18/10⁶ in females) was only one-half of that in Sweden, on the average, only one case of chordoma will be diagnosed annually in Finland (population 4 6 million) In the material compiled from the Swedish Cancer Registry from 1959 to 1965, chordomas constituted 3 9 per cent of all bone tumours (Cancer Incidence in Sweden 1959–1965) In Finland, the corresponding figure was 1 5 per cent

The anatomical distribution of tumours along the spine is related to the source from which the patients are drawn (radiotherapy clinic, neurological unit, cancer registry, etc) Most often the sacrococcygeal region is affected this was also found to apply to our series The age and sex distribution of our series corresponds with many other series which have indicated a male preponderance, and the highest incidence in middle and old age (e g Higinbotham et al 1967)

As wide variations were apparent in the modes of therapy, and the patients concerned underwent treatment over a long period of time, this series does not provide a basis for any conclusion being drawn as to the most effective treatment Of course, a radical operation seems desirable, and probably offers the only hope for the patient's permanent cure (Gentil & Coley 1948) Unfortunately, anatomical circumstances mean that radicality is the exception rather than the rule (Pearlman & Friedman 1970) Spheno-occipital and vertebral chordomas are hardly ever curable Although the value of postoperative radiation is difficult to assess, it should be attempted particularly in cases of non-radical operation (Pearlman & Friedman 1970) despite the radio-resistance offered by chordomatous tissue in general

The reported frequencies of metastases vary, ranging from 0 per cent (Dahlin & MacCarty 1952) to 43 per cent (Higinbotham et al 1967) During the course of the disease, up to 60 per cent of our cases developed distant metastases, in only three instances, however, was this confirmed by biopsy or at autopsy On occasion, it has been stated that chordoma is a semi-malignant neoplasm We regard this as an underestimation the high frequency of local recurrences, and the fact that metastases are often encountered, clearly indicate that chordoma is a malignant tumour Admittedly, rather long periods of survival are attainable, this means that chordomas grow slowly Nonetheless, this demands active treatment of the recurrences, and even of the metastases, although sooner or later the disease may prove fatal In a series of 46 patients reported by Higinbotham et al (1967), 9 per cent of the patients were free from disease after a follow-up period of five years The corresponding figure in our series was 5 per cent after 3 years (1/20)

The histological details of the chordoma do not provide a basis for evaluation of the patient's prognosis (cf Heffelfinger et al 1973), a tumour with very little cellular pleomorphism can cause the death of the patient within a few months The prognosis is largely determined by the extent of the tumour at the time of diagnosis (upon which depends the radicality or non radicality of the operation), and probably also by some unknown factors of the host, the patient himself

CASE REPORTS

Case 1 H D A 51 year old male was the driver of an automobile which rolled 100 feet down an embankment Initially he was seen at another hospital and was found to be semicomatose without any focal localizing signs Twenty four hours later when he regained consciousness he was noted to be a C_7 tetraplegic with some sacral sparing Radiographs of the spine showed a wedge compression fracture of the T_6 vertebral body (Figure 1 A) and cervical spine radiographs were interpreted to be normal On myelography a complete block was noted at the C_6 inter vertebral space Decompression laminectomy (C_5 T_1) was done revealing fracture of the right lamina of C_6 and a hyperemic spinal cord with out evidence of contusion At 2 months follow ing the initial injury the patient was allowed to sit up *Three weeks* later subluxation of C_6 on C_7 (Figure 1 B) was detected and anterior fusion was performed

Comments In this patient the diagnosis of spinal cord injury was delayed because of un consciousness Twenty four hours later when the patient regained consciousness the level of paralysis indicated injury to the spinal cord although the radiographs of the cervical spine appeared to be normal Myelography revealed a block at C_6 and fracture of the right C_6 lamina was found during laminectomy

Case 2 D M An 18 year old female college student was a passenger in the rear seat of an automobile which was involved in a two vehicle head on collision and the patient was thrown out of the car There was no loss of conscious ness and she noticed immediately loss of sensa tion in the lower half of her body and inability to move the lower limbs On admission to hospital she was found to be paraplegic with complete sensory and motor loss below T_5 This patient also had a Horner's Syndrome on the right side Radiographs of the spine showed fracture dislocation of $T_{5\ 6\ \&}$ with maximum compression dislocation at T_6 and fractures of the spinous processes of $C_{6\ 7}$ and T_1 (Figure 2) On decompression laminectomy (T_4–T_8) the spinal cord was reported to be macerated

Comments The severity of the initial trauma was obvious Thoracic spine injury was the im portant injury for the paraplegia In the absence of any evidence of bruising of the neck it is un likely that the Horner's Syndrome was secon dary to direct neck injury The fractures of the spinous processes of $C_{6\ 7}$ and T_1 with right Horner's Syndrome suggest the possibility of injury to the cervical spinal cord or intraspinal root injury



Figure 1 (Case 1) A Left compression fracture of T_6 cervical spine 12 weeks fol C_6 vertebral body on C_7

Acta orthop scand 47, 52–58 1976

MULTIPLE NON-CONTIGUOUS INJURIES TO THE SPINE

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Over a period of 4 years 120 patients with an identified neurologic defect secondary to spinal cord injury were admitted to the UCD Sacramento Medical Center Of these cases five (4 2 per cent) were found to have multiple non contiguous injuries to the spine which would have been capable of producing complete neurologic loss at either level Proper treatment is dependent on diagnosis and correct diagnosis is dependent on the awareness that multiple non contiguous injuries to the vertebral column can occur in victims of sever motor vehicle accidents

Key words spinal injury, spinal cord injury paralysis

Accepted 18 vii 75

In high speed automobile accidents the injuries that the patient may receive are almost always multiple and the examining physician must be alert to the possibility of multiple organ system involvement The neurologic injury which is perhaps the easiest to overlook is the presence of spinal cord damage in an unconscious patient, and this may remain untreated until the patient regains consciousness Another combination in which one neurological injury can be concealed by another is the presence of multiple non-contiguous injuries to the spine, with either or both lesions being capable of producing the paralysis

Multiple non-contiguous injuries to the spine, as used in this text, are defined as injuries to the vertebral column at more than one site, with these sites being separated by an area of normal spine A review of the literature revealed a paucity of references on this subject The purpose of this paper is to report five patients with such a problem who represent 4 2 per cent of the patients with spinal injury admitted to the UCD-Sacramento Medical Center during the period January 1970 to December 1973 Clinically the level of neurological deficit was assessed by repeated motor and sensory examination Osteoarticular injury to the vertebral column was evaluated by radiographs Evidence of injury to the vertebral column found at the time of operation is also included where appropriate Awareness that such multiple injuries to the spine can occur will lead to more adequate evaluation and permit early recognition and treatment of these disorders so as to avoid deterioration of neurologic function



Figure 3 (Case 3) A Left—x-ray of thoracic spine, taken at time of admission reveals compression fracture of T_{11} vertebral body B Right—x-ray of cervical spine, taken at time of admission, reveals fracture dislocation of C_7 vertebral body on T_1

Figure 4 (Case 3) A Right—x ray (tomogram) of thoracic spine taken 4 weeks following injury This tomogram adequately demonstrates comminuted fracture of T_8 vertebral body plus fracture of the inferior angle of T_8 and wedging of the body of T_7 Dislocation of T_8 vertebral body on T_9 was more evident on the plain films B Left—x ray of cervical spine, taken 4 weeks following injury, reveals compression fracture of C_5 with subluxation of C_4 vertebral body on C_5

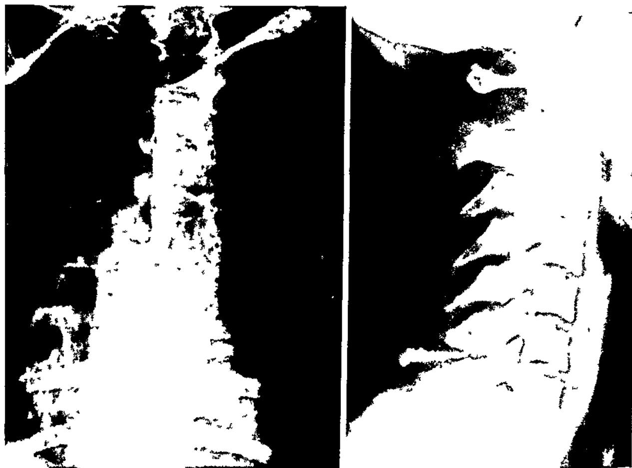


Figure 2 (Case 2) Left—x-ray of thoracic spine taken at time of admission, reveals fracture dislocation of T_5, T_6 & T_7 with maximum compression and displacement at T_6 Right—x ray of cervical spine taken at time of admission, reveals fractures of the spinous processes of C_6 and C_7 The spinous process of T_1 was also fractured but is not visible on this plate

Case 3 S G An 18 year old male was the driver of an automobile which rolled over on relatively level ground He noticed inability to move his upper and lower limbs immediately following the injury Loss of sensation below T_{10} and loss of motor power in both lower limbs was detected in the emergency room One hour later he was noted to have sensory loss below T_6 and motor loss below C_7 X-rays of the thoracic spine revealed wedge compression of T_{11} vertebral body (Figure 3 A) Since the level of paralysis rapidly ascended to C_7, radiographs of the cervical spine were obtained, which showed a fracture dislocation of C_7 on T_1 (Figure 3 B) Two years following the injury, the patient is still a tetraplegic below the C_7 level

Comments At the time of the initial examination in the emergency room with sensory and motor loss below T_{10} and radiographic evidence of a wedge compression fracture of T_{11}, the examining physician was satisfied with the diagnosis Since there were no symptoms or signs referable to the cervical lesion at that time it was overlooked until an hour later because of the ascending motor level to C_7, radiographs of cervical spine were obtained showing fracture dislocation of C_7 on T_1

Case 4 E W A 23-year old, slightly obese male, was a passenger in the front seat of a pickup truck which was forced from the road and hit a fence The patient was thrown out of the vehicle At the time of admission to hospital the patient was found to be paraplegic with motor and sensory loss below T_5 There was patchy sparing of sensation in the lower limbs In the upper limbs there was hypoesthesia below C_5 dermatome and asymmetric weakness of wrist flexors and extensors Deep tendon reflexes were hyperactive in the lower limbs The Babinski sign was positive bilaterally Radiographs of the spine showed fracture dislocation of T_5 on T_6; subluxation of C_4 on C_5 and a wedge compression fracture of C_5 vertebral body (Figure 4 A & B) Following placement of Crutchfield tongs for cervical traction, decompression laminectomy T_5–T_7 was done The lamina of T_6 was found to

Table 1 Injuries observed

Case No	Cervical spine Vertebral	Cervical spine Neurological	Thoracic and lumbar spine Vertebral	Thoracic and lumbar spine Neurological	Associated injuries
1	Fracture Rt lamina C_6 (found during operation)	Tetraplegia	Wedge fracture T_6		Multiple bruises closed head injury, unconscious 24 hours
2	Fracture spinous processes C_6 T_1	Horner's Syndrome right side	Fracture dislocation $T_{5\ 6}$	Paraplegia T_5	Fracture left radius fracture pelvis sacro iliac separation pulmonary contusion
3	Fracture subluxation C_7–T_1	Tetraplegia C_7	Wedge fracture T_{11}	Sensory loss below T_6	Multiple bruises cerebral concussion
4	Fracture subluxation $C_{4\ 5}$	Sensory loss below C_5 with sparing asymmetric upper limb weakness	Fracture dislocation T_{5-6}	Paraplegia T_5	Fracture clavicle (Rt) fracture 4th rib (Rt), pulmonary contusion rupture spleen
5	Wedge fracture of C_6	Normal	Wedge fracture L_1	Normal	

Griffith et al (1966) in a series of 250 cases with spinal injuries, reported only five cases (2 per cent) with injury to the dorsal and lumbar regions Bentley & McSweeney (1968) reported four cases of co existing injuries to the cervical and thoracic spine They were able to identify only one case with injury to the cervical and lumbar spine in the report published by Kossen (1965) It is probable that there are many other cases of non contiguous injuries to the spine as yet un reported There is a paucity of references on this subject in the medical literature In this study five cases out of 120 (4 2 per cent) were found to have multiple non contiguous injuries to the spine cer vical and upper thoracic, 3, and cervical and lower thoracic or lumbar, 2 The four victims of automobile accidents were not wearing seat belts and all had other as sociated injuries (Table 1)

Early diagnosis of the specific type and severity of the injury to the vertebral column is of critical importance, as treatment and prognosis depend on accurate assessment of the degree of damage to the spine In patients with complete tetraplegia associated with fracture, dislocation, or fracture-dislocation of the cervical spine, a separate injury to the spine at a lower level would be concealed If the cephalad lesion is complete the patient's problem would probably not be significantly worsened if the lower lesion was overlooked, unless there was a severe structural instability But this is not true in the patient where the caudal lesion is neurologically symptomatic and the cephalad lesion is missed Thus it is obvious that in a patient with clinical evidence of paraplegia and radiographic evidence of injury to the thoracic or lumbar spine, a missed injury to the cervical region could convert the patient into a tetraplegic If the initial thoracic

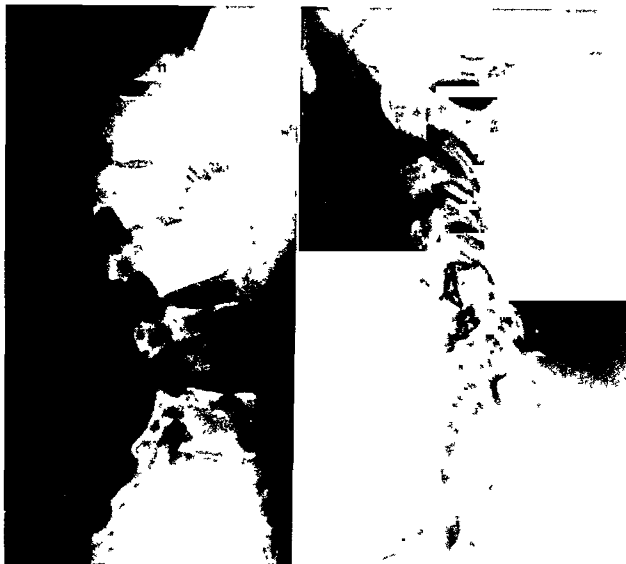


Figure 5 (Case 4) A Left—x ray of thoracic spine at the time of admission revealed wedge compression fracture of L_1 vertebral body B Right —x ray of cervical spine showing wedge fracture of C_6 and subluxation of C_6 on C_7

be fractured and the spinal cord was reported to be normal Two years following the injury, the patient has normal motor power in all four extremities and actively participates in sports

Comments The initial neurological findings could easily have been explained by the flexion rotation injury to the thoracic spine Had the subtle evidence of the cervical lesion been over looked, or explained away as peripheral nerve injury, the patient might easily have become a permanent tetraplegic from the cervical spine injury

Case 5 D H An 18 year old male was involved in a motorcycle versus automobile accident Two hours later in the emergency room he complained of pain in the lower part of his back There was no detectable neurological deficit Radiographs of the spine showed wedge fracture of L_1 vertebral body and fracture subluxation of C_6 on C_7 (Figure 5 A & B) The patient was hospitalized for one week and was immobilized in a sternal occipital mandibular immobilization device

Comments In this patient the severity of the vertebral injury was obvious (Figure 5 A & B) but there was no neurological injury By early diagnosis and appropriate treatment any deterioration in functional status was avoided

DISCUSSION

The incidence of multiple non-contiguous injuries to the spine is probably very low

Acta orthop scand 47, 59-62 1976

AN UNUSUAL CASE OF HISTIOCYTOSIS X IN THE SPINE

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A case of spontaneously healing histiocytosis X followed over 9 years is presented The lesion was located in the cervical and dorsal spine and had unusual radiological features such as soft tissue swelling involvement of the pedicles and recovery with fusion between adjacent vertebra

Key words histiocytosis X, eosinophilic granuloma, vertebra plana, bone tumours

Accepted 12 viii 75

It has already been shown that skeletal involvement of histiocytosis X can mimic many other conditions (Ennis et al 1973 Poulsen et al 1975, Thommesen & Poulsen unpublished data) and exact diagnosis must in most cases rely on biopsy However, lesions in the spine in children with development of a vertebra plana are regarded by many as pathognomonic of histiocytosis X until proven otherwise (Ennis et al 1973) especially if the following radiological features for a solitary lesion are fulfilled

1 Only one vertebra involved
2 Adjacent discs intact above and below the diseased vertebra
3 Disc space about a third wider than the next space above and below
4 Homogeneous density of the collapsed vertebral body

These four classic criteria have been laid down by Compere et al (1954) in the diagnosis of eosinophilic granuloma However, the rarity of certain features has been emphasized by Kieffer et al (1969)

1 Soft tissue swelling is rare
2 Involvement of the pedicles is rare
3 Fusion between vertebra after recovery is rare
4 Cervical involvement is less frequent

We have recently reviewed a case of probable spontaneously healed histiocytosis X followed over 9 years, which primarily caused some diagnostic problems and during the course showed some less frequent radiological features

CASE REPORT

An 11 year old boy was admitted to the Orthopaedic Hospital with pain in the neck after an adequate trauma 1 month previously The primary X ray gave rise to a suspicion of subluxation between the third and the fourth vertebral bodies (*Figure 1* first row, first X ray from 1966) Physical findings were slight limitation of movement in the neck. The patient was treated with traction followed by plaster ban

or lumbar lesion was incomplete and could possibly show neurological improvement, the results would be even more disastrous if this patient were allowed to become tetraplegic because of the negligence and inadequate treatment of the missed injury to the cervical region

The comatose patient poses special problems in diagnosis for the possibility of injury to the spinal cord Loss of voluntary movement and absence of sensation may either be overlooked due to the reduced level of consciousness or might even be interpreted to be due to intracranial injuries Since the conventional neurological examination cannot be adequately carried out in unconscious patients the examining physician is forced to rely on his suspicion and place greater than usual emphasis on radiologic examination In comatose patients radiographic examination of the entire spine is essential with particular attention to the more vulnerable mobile cervical spine and the cervicothoracic and thoracolumbar junctions In cases where simple radiographs are inconclusive or suspicious special views of the areas in question should be obtained All patients with a suspected injury to the cervical spine must be immobilized until affirmative or negative proof can be obtained

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dage A few months later the diagnosis eosinophilic granuloma was established because of the typical X ray findings in the cervical spine the same year (Figure 1) Four months later X ray of the dorsal spine showed partial collapse of the seventh thoracic vertebral body (Figure 1 second row X rays from 1967) ESR was 33 mm/h Serum electrophoresis showed elevated α_2 globulin normal γ globulin

Survey X ray revealed no other lesions After a short period of local pain he had no symptoms for the next two years when pain in the right shoulder initiated further X rays revealing partial collapse of the sixth vertebral body Figure 1 first row X ray from 1969) The X ray findings were checked and at the last visit in 1975 he was without symptoms and X ray showed partial regeneration of both the cervical and dorsal lesions

DISCUSSION

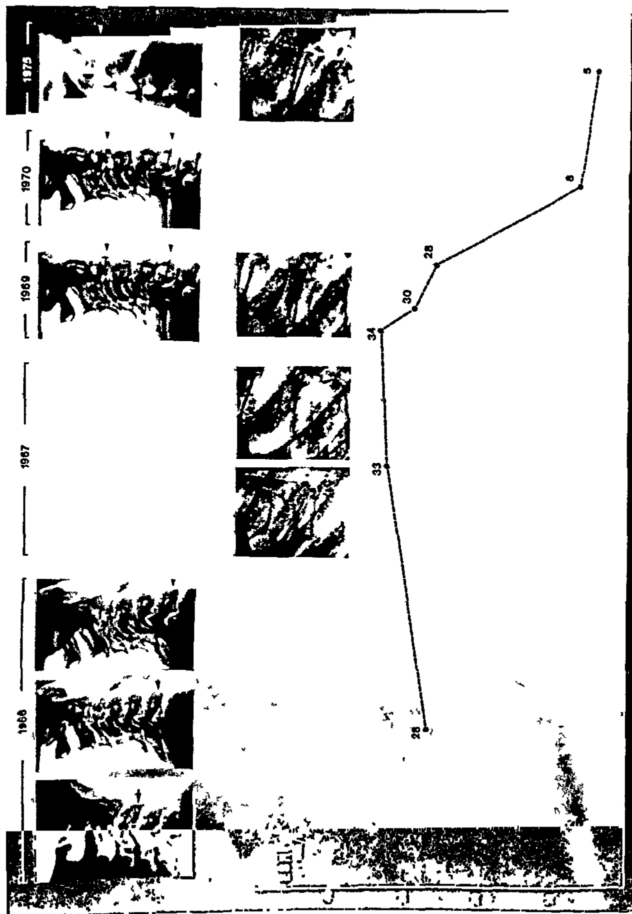
The patient was primarily treated for subluxation between the third and fourth cervical vertebral bodies although the movements of the cervical spine were only slightly limited Retrospectively one has to acknowledge a slight compression of the third vertebral body with no sign of fracture and a "washed out" appearance due to osteoporosis However, the subsequent X-ray picture from 1966 established the diagnosis eosinophilic granuloma based on Compére et al 's (1954) criteria It should be noted that soft tissue swelling also is present (Figure 2), and might simulate an inflammatory process but the ESR level was not characteristic and serum electrophoresis showed a raised α_2 globulin level with no γ globulin response

The course of the affection in the seventh thoracic vertebral body followed the criteria laid down by Compere et al (1954) with almost complete restoration in 1975 giving rise to the appearance of a "bone within bone" (Figure 1) Comparing the X-rays of the cervical spine from 1966 with those from 1969, it is obvious that also the sixth cervical vertebral body has been involved and recovery has taken place simultaneously with the third vertebral body Partial fusion with the adjacent vertebra is also seen and furthermore a tomogram from 1975 shows that also the pedicle has been involved resulting in complete fusion



Figure 2 X rays of the cervical spine over a period of 3 months (a b c) illustrate the soft tissue swelling anterior to the third cervical body (b c) this has disappeared two years later (d)

Figure 1 At the top the years of interest to this case presentation are indicated At the bottom the ESR s [illegible] of t[illegible] the [illegible] men[illegible] the [illegible] cent[illegible] sixth and seventh vertebral body seen on the tomogram in 1975 In the second row of pictures the lesion in the seventh thoracic vertebral body is shown with partial regeneration occurring in 1975


1975
1970
1969
1967
1966
5
6
28
30
34
33
28

Acta orthop scand 47, 63–66, 1976

CERVICAL SPONDYLOLISTHESIS

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A case is reported of cervical spondylolisthesis in a 12 year-old girl The cervical spondylolisthesis has not progressed in the 2 years of observation

Key words cervical spondylolisthesis, spina bifida, cervical pain

Accepted 8 vii 75

Spondylolisthesis is an abnormality that is often seen in the lumbar spine It is rare to find it in the cervical region although congenital abnormalities of the cervical spine are often observed The anomaly consists of bilateral defects in the interarticular portions of the vertebral arch (i e, bilateral spondylolysis) with consequent slipping of the corresponding vertebral body The condition was first described by Perlman & Hawes in 1951 Subsequent case reports have been presented by several authors (Kau 1954, Schlüter 1956, Durbin 1956, Lissner, Csákány & Almos 1959, Niemeyer & Penning 1963, Wiedhopf 1965, Isobe et al 1966) In this case report cervical spondylolisthesis of a 12-year-old girl is described

CASE REPORT

A 12 year-old school girl who had no history of an accident complained of pain in the cervical region and the right arm The pain became accentuated by holding the same posture for a long time On neurological examination, no abnormality was found There was no limitation of movement nor was there any radiation of the pain into the thoracic area, into the shoulders and arms, or into the hands Roentgenograms (Figures 1 A, 1 B, 1 C) were taken in the antero-posterior, lateral and both oblique projections of the cervical spine The sixth cervical vertebra and the superincumbent vertebrae were displaced forward on the posterior arch of the sixth cervical vertebra and on the seventh cervical vertebra At this level there was an increase of the cervical lordosis The defects appeared to be in the pedicles of the sixth cervical vertebra. The articular pillars of the sixth cervical vertebra were underdeveloped and had become shorter in length, and the articular pillars of the fifth cervical vertebra were not fully developed There was a spina bifida of the sixth cervical vertebra To determine the instability of the patient's cervical spine, a functional roentgenographic investigation was carried out using the technique

Table 1 The angle of mobility of the cervical spine

	1972 9	1974 9	Zeitler (11–14 y)
C 1/2	20°	25°	
C 2/3	20°	15°	17 5°
C 3/4	30°	20°	25 5°
C 4/5	25°	15°	29 5°
C 5/6	15°	25°	27 5°
C 6/7	10°	20°	23°

between those parts in the second third and fourth cervical segments

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Table 2 The symptoms and X ray findings in cervical spondylolisthesis

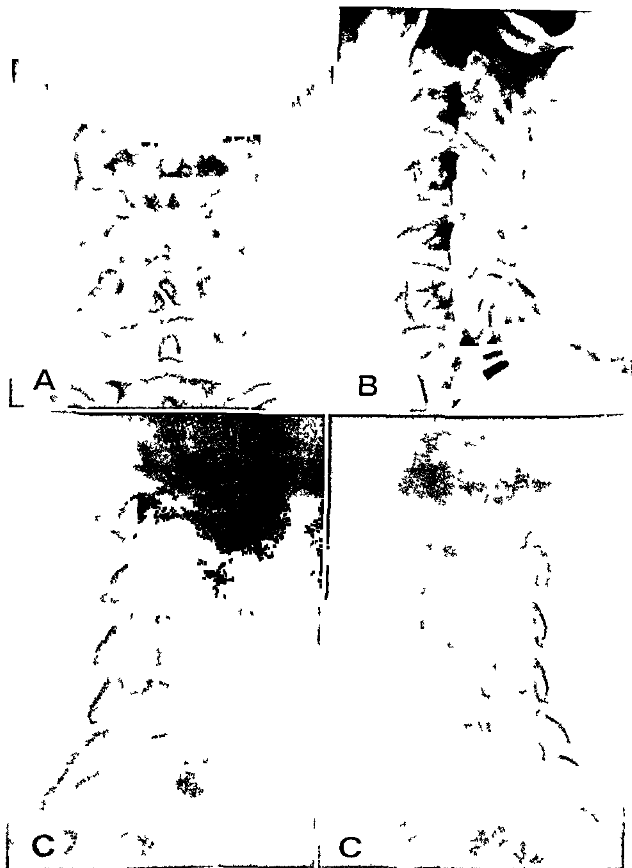
Author and year	Age	Sex	Symptom	X ray finding: Spondylolysis	Spina bifida	Spondylolisthesis
Perlman & Hawes (1951)	19	Male	Nuchal pain	C6+	C6+	C6/7
Kau (1954)	8	Male	Torticollis	C6+	C6+	C6/7
Schluter (1956)	42	Male	Cervical pain	C6+	C6+	C6/7
	55	Male	Nuchal pain	C6+	C6+	C6/7
Durbin (1956)	25	Male	Cervical pain	C4+		C4/5
Lissner (1956)	42	Male	Nuchal pain	C5+	C5+	
				C6+		C6/7
Csakány & Almos (1959)	41	Male	Retrosternal pain	C6+	C6+	C6/7
Niemeyer & Penning (1963)	40	Male	Dysphagia	C6+	C6+	C6/7
Wiedhopf (1965)	17	Male	Cervical pain	C6+	C6+	C6/7
Isobe et al (1966)	57	Male	Shoulder pain	C6+	C6+	C6/7
	33	Male	Cervical pain	C6+	C6+	C6/7

f l Penning The results of the functional roentgenographic investigation of the patient s spondylolisthetic vertebra are shown in Table 1 The range of movement of the patient s cervical spine seemed to be almost in the normal range with respect to Zeitler's data on the motion of children s cervical spines (Zeitler & Markuske 1962) When discovered anterolisthesis in the ase of the 12 year-old girl was about 3 0 mm The instability was not apparent in every cervi cal vertebra Based on the data obtained a mfortable collar was designed for the patient The cervical pain decreased immediately after fixati n of the collar Two years after the first nsultation the patient was examined roent gen graphically The range of movement of the cervical spine is shown in Table 1 The degree of m vement of each cervical vertebra is almost the same as that of 2 years previously Antero l sthesis is about 2 5 mm From this evidence it ems that the patient s cervical spondylolis thesis has not progressed

DISCUSSION

Eleven cases have been reported in nine publications (Table 2) In all case reports, the cervical spondylolisthesis has been found in men The sixth cervical vertebra was the region of predilection According to Hadley (1946), the spondylolysis of the cervical spine was a con genital anomaly of the spine and was induced by developmental disturbance of the cervical laminal arch Hadley (1946) also suggested that if the symptoms of cervical spondylolysis were more severe, the relative frequency of the disease would be higher Caffey (1967) mentioned that the cervical spondylolisthesis might be induced by disturbance of the ossification of the neural arches of the cervical vertebrae in the early months of fetal life Csákány & Almos (1959) named the cervical spondylolisthesis "C6 Symptomen Komplex" In that case it was accompanied by spina bifida of the sixth cervical vertebra Treatment or follow-up has been reported for four of the eleven patients in the literature The treatment in Kau's case (1954) consisted of performing a tenotomy of the sternocleido muscle For one case in Isobe's report (1966) conservative therapy was administered in the other case an anterior spine fusion was performed Niemeyer & Penning (1963) mentioned that functional roentgenographic investigation was

Figures 1 A 1 B 1 C Anteroposterior lateral and oblique roentgenograms of the cervical spine of a 12 year-old school girl with spondylolisthesis and spina bifida of the sixth cervical vertebra The body of this vertebra shows ventral displacement relative to the seventh cervical vertebra


A
B
C
C

Acta orthop scand 47, 67-69, 1976

HEMIPELVIC DISLOCATION COMPLICATED BY DISLOCATION OF THE IPSILATERAL HIP

A Case Report

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The case presented involves a rare combination of severe injuries to the hemipelvis and ipsilateral hip joint Suggestions are made with regard to treatment

Key words hemipelvis dislocation, hip dislocation

Accepted 10 x 75

When various injuries to the pelvis concomitantly include diastasis of the symphysis, separation of the sacro-iliac joint, and cephalad dislocation, a well-known and often-described clinical picture is obtained However, when the findings are accompanied by ipsilateral dislocation of the hip, a rare combination of injuries ensues and is felt to warrant reporting

CASE REPORT

The patient was a 24 year old female medical student who was injured when the car in which she was travelling overturned At the time, she occupied the front right hand (passenger's) seat and she was not wearing a safety belt

Her various injuries centred on the pelvis and X ray examination of the region revealed a separation of the right sacro iliac joint The pelvis in addition to cephalad dislocation, showed diastasis of the symphysis, and there was a posterior dislocation of the right hip

In accordance with standard treatment practices pertaining to severe injuries involving the pelvis the patient was taken to the operating room where full muscle relaxation was obtained under general anaesthesia Thereupon, repeated attempts at closed reduction of the femoral head were undertaken but proved unavailing As a probable result of these manipulations, a large haematoma appeared in the pubic area, and both labia became increasingly oedematous Since it was obvious that only open reduction could correct the problem, the approach of Osborne was employed to open the capsule and expose the femoral head and neck (Gibson 1950) Further attempts to replace the femoral head failed because of the profound and erratic instability of the pelvis Finally, the gluteus minimus and medius muscles were dissected away from the greater trochanter, and then, reduction of the head of the femur was effected with comparative ease The glutei were subsequently sutured to their insertion, and the procedure was thus completed.

On her return to the ward, the patient was placed in a dual pelvic sling, and skeletal traction was applied to the right tibia Thereby, adequate reduction of the pelvis was obtained, and these measures were continued over an 8-week period. Thereafter, she began to ambulate, at first with the aid of crutches, and within about 4 months, she was walking freely, bearing weight on both feet Now, some 2 years after the accident, there are no signs of avascular necrosis, the pelvis is firmly stabilized, and the patient shows no limitation of movement

useful for the determination of treatment for the spondylolisthesis

In their case, the mobility of the spondylolisthetic vertebra was in the range of 10–25 degrees Because this angle was in the normal range, operative procedure was not used The mechanism of nuchal pain, or cervical pain, is not clearly understood In our case, as in Niemeyer's case, abnormal mobility of the vertebra was not apparent It seems reasonable to assume that the cervical pain may be caused by abnormal strain on the vertebral body or by abnormal motion in the pedicles Neurological symptoms have not been cited in any publication If the anterolisthesis of the spondylolisthetic vertebra exceeds a certain limit, neurological symptoms must occur In all reported papers the anterolistheses were within 3 0 mm It is supposed that the anterior ligament complex protects against anterolisthesis of the vertebral body

ACKNOWLEDGEMENT

The authors wish to express their sincere appreciation to Professor Norio Abematsu for kindly reviewing this paper

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Both Holm and Dunn & Morris describe a large number of complications arising from severe pelvic injuries including lacerations or contusions of the urinary bladder, damage to the urethra and to the sciatic nerve perianal laceration and ruptured testes, these occurring in a majority of their patients

In our patient, there were a large number of erythrocytes in the urine during the first 2 days of her hospitalization, but she developed no signs of significant injury to the urethra or to the urinary bladder

The oedema and the haematomata of both labia were caused by the repeated attempts at reduction of the femoral head in the face of the erratic movement of the hemipelvis There was no injury to the sciatic nerve

In view of our experience in this instance we recommend (1) that attempts at closed reduction of the femoral head in such cases be avoided and that open reduction be considered the method of choice from the outset (2) When (due to pelvic instability) difficulties in open reduction are encountered the gluteus medius and minimus muscles can be dissected from the greater trochanter and then re sutured to their insertion following reduction of the femoral head Alternate procedures avoiding transection of the glutei, as preferred by Campbell, might employ, for example, Ollier s lateral U approach to osteotomy of the greater trochanter (Ollier 1963), fixation of the osteotomized greater trochanter could then utilize Hoffman s osteotaxic apparatus (Hoffmann 1961) or Muller s techniques following the insertion of Kirschner wires (Muller et al 1970) An acquaintance with these various techniques, their advantages and limitations would of course govern the choice of procedures

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Figure 1. Total disruption of the pelvis with diastasis of the symphysis pubis, sacro-iliac separation and cephalad dislocation of the left hemipelvis and posterior dislocation of the right hip.



Figure 2. Status post-reduction of the hip and reduction of the pelvis following treatment with dual pelvic sling and skeletal traction.

DISCUSSION

Though the exact mechanisms underlying these injuries cannot be definitely explained, a re-enactment of the accident permits the following hypothesis.

During the collision, the patient's knee rammed the dashboard, and the impact resulted in a posterior dislocation of the right hip. Following the collision, the car overturned and the patient, in being thrown clear, suffered a right hemipelvic dislocation in the fall.

Holm (1973), in his paper on the treatment of pelvic fractures and dislocations, describes 59 cases, among whom only 16 (27 per cent) had unstable fracture dislocations of the pelvic ring. Of these, only one case showed sacro-iliac diastasis, fracture of the superior and inferior pubic rami, fracture of the acetabulum, and dislocation of the left hip joint. However, he does not indicate the nature of the dislocation nor does he detail the method of treatment.

Dunn & Morris (1968) describe 149 patients with pelvic injuries, of whom 34 had unstable fractures of the pelvic ring. Two of these suffered total disruption, but none of these patients sustained a dislocation of the hip joint in addition to the pelvic injury.

his conceptions regarding the superiority of osteogenetically self locking intra medullary fixation Regarding operative techniques the problem has largely been the question of using either the Gibson incision or the southern exposure Both types of technique can be said to have certain pros and cons

Of main interest today are the late results and especially what they are in more or less skilled hands As we know the main indication for operation has been a fresh fracture of the femoral neck a traumatic condition treated not infrequently by general surgeons The operations in our series have been per formed by residents and surgeons with a wide variety of operative skill and experience

MATERIAL AND METHODS

Endoprosthetic reconstruction of the proximal end of the femur with the self locking Austin T Moore prosthesis was performed during the period 1965-1972 on 109 hip joints of 106 patients at the Department of Surgery Oulu University Hospital Finland. The majority of the patients were elderly females with fresh fracture of the femoral neck or late complica tions of same (Table 1 and 2)

Table 1 Sex and average age

Sex	No of cases	Age (years)
Females	85	72 (34-89)
Males	21	70 (41-88)
Total	106	71 5 (34-89)

Table 2 Diagnosis

Fresh femoral neck fracture		85
pathological fracture	2	
Old femoral neck fracture		21
non union	12	
avascular necrosis	7	
fatigue fracture with total dislocation	2	
		106

Table 3 Concomitant diseases and injuries

Cardiovascular disease		50
heart failure	22	
coronary artery disease	13	
cardiac arrhythmias	7	
hypertension	7	
valvular defect	1	
Central nervous disease		16
arteriosclerosis	8	
hemiplegia	4	
parkinsonism	2	
apoplexia cerebri	1	
epilepsy	1	
Rheumatoid arthritis		9
Diabetes		8
Pulmonary disease		8
Urinary infection		7
Malignancy		5
Coincident fracture		3
Miscellaneous		23

Very few of the patients operated upon were in an uncomplicated general condition before the trauma and/or operation (Table 3) The majority preoperatively received medical atten tion drug treatment and physical exercises (Table 4)

Preoperative hospital stay was on average 5 0 days. All fresh fractures were primarily immobilized, usually by traction The majority of the pseudarthroses and necrotic heads had been subjected to various procedures of nailing an average of 10 months before (Table 5) Nearly all the operations were performed in intubation general anaesthesia under the con trol of an anaesthetist.

The surgeons were evenly divided between res idents and specialists in at least general surgery

Table 4 Preoperative and postoperative medication

Medication	Pre oper	Post oper *	Total
Heart and hypertensive disease medication	66	2	68
Sulfonamid	25	21	46
Antibiotics	16	37	53
Anticoagulant	6	7	13
Anabolic steroids	5	1	6

* Postoperatively started.

Acta orthop scand 47, 70–78 1976

THE MOORE VITALLIUM FEMORAL-HEAD PROSTHESIS IN FRACTURES OF THE FEMORAL NECK

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A follow up is given of early and late results in 109 arthroplasties with the self locking Austin T Moore vitallium femoral head prosthesis in fractures of the femoral neck on 106 patients Operative indication was usually fresh medial fracture of the femoral neck in an elderly woman or its late complication The surgery was performed in a unit for general surgery also engaged in pre and postgraduate teaching activities Many operations were performed by residents engaged in general surgery or orthopaedics Point scores according to a modification of Merle D'Aubigné s classification showed excellent or at least good results in 81 per cent of the 69 mobile patients Because of deteriorated general physical condition 11 patients were chronically bed ridden Five patients could not be reached In three instances the prosthesis was removed 21 patients died three during the stay in hospital and 18 later for reasons not connected with the operative procedure The mortality during 40 months of observation corresponded fairly well to that expected in the age group for the population as a whole

Key words Moore arthroplasty femoral neck fracture

Accepted 5 vii 75

Failures in nailing intracapsular fractures of the femoral neck are frequent even with the sliding nail There is a frequency of technical failures (too long nail, too short nail etc) of 16 per cent, non union 8 6 per cent, avascular necrosis 17 2 per cent, and Girdlestone pseudarthrosis 3 7 per cent (Greenberg et al 1973)

Endoprosthetic replacement of the femoral head in geriatric fractures of the proximal femur has been more and more accepted as a method-of-choice

The superiority of the Moore prosthesis in clinical practice over the other devices once prevailing has been established by inter al Hinchey & Day (1955) and Stinchfield et al (1957) Moore & Bohlman's (1943) choice of vitallium in 1939 has stood well the test of time and strain

The architecture of the prostheses has undergone much development since then However, the composition designed by Moore (1951) has remained rather unchanged until now The type of fixation, either endoprosthesis direct to bone or via cement to bone, has been widely discussed Moore (1957) has not changed

Table 9 Numerical evaluation of the hip joint according to d Aubigné

Score	Pain	Mobility	Walking
0	Very severe continuous pain	Ankylosis with bad position of the hip	Unable to walk.
1	Very severe pain preventing sleep	Clinical ankylosis with little or no deformity	Only with crutches
2	Severe pain on walking Inhibited in all work	Flexion 0–40° Abduction 0° or slight deformity	Only with 2 sticks
	Tolerable pain interfering with work.	Flexion 0–60°	Less than 1 hour with stick. Very difficult without stick
	Only pain after walking Subsides on resting	Flexion 0–80° Able to lace shoes	1 stick for long distances Limited without stick
	Negligible and intermittent pain not interfering with work.	Flexion 0–90° Abduction < 25°	A slight limp without a stick
	No pain	Flexion > 90° Abduction > 25°	Normal

ts could satisfactorily perform all daily activities In nine cases there were moderate to severe restrictions

arly complications (Table 11)

Three patients (2 7 per cent) died during hospital stay two of them very early and one after 4 weeks of blood disease

Deep infection in three patients (2 7 per cent) led to removal of the prosthesis and spontaneous Girdlestone joints in all instances

Dislocation of the Moore head occurred twice both times in patients with pseudarthrosis from fatigue fracture resulting in atrophy of the acetabular rim (1 8 per cent) (Figure 1) Reposition by closed manoeuvres was performed with subsequent immobilization in internal rotation and abduction for 4–8 weeks with plaster cast No further treatment was needed and the prognosis was favourable

Accidental fractures of the proximal femur occurred five times during insertion of the prosthesis Treatment consisted of prolonged immobilization The fractures healed well In none of the

Table 10 System of classification of end result on the basis of total score modified by pain thresholds

End result	Score	Criterion
Poor	0–7	pain 0–2
Fair	8 12	pain >3
Good	13 16	pain >4
Excellent	17 18	

Table 11 End results in 69 patients with Moore endoprosthesis of the hip joint (excluding 11 cases with inability to walk as a result of general disease Table 12)

Poor (including 3 cases with prosthetic removal)	5	(7 3 per cent)
Fair	8	(11 6 per cent)
Good	35	(50 7 per cent)
Excellent	21	(26.2 per cent)
Total	69	(100 per cent)

Table 5 Time lapse between injury and Moore operation

Diagnosis	No of cases	Time
Fresh femoral neck fracture	85	5 days
Old femoral neck fractures (non union, avascular necrosis)		
no earlier treatment	5	25 months
failure after treatment	16	10 months

Table 7 Duration of stay in hospital and location of convalescence period

Mean duration of stay in hospital	
preoperatively	5 days
postoperatively	12 days
total	17 days
Location of convalescence	
home	31 patients
old people's home	13 patients
hospital for chronic diseases	62 patients

Table 8 Follow up series

Follow-up		80 (75 5 per cent)
able to walk	69	
unable to walk from general disease	11	
prosthesis removal	3	
Follow-up contact lost		5 (4 7 per cent)
Deaths		21 (19 8 per cent)
Total		106 (100 per cent)

The southern incision was most often utilized, followed by the Gibson incision (Table 6)

The postoperative rehabilitation included verticalization after 2 7 days on average and walking with aids after 5 days on average Postoperative medication was needed in many patients (Table 4) Postoperative hospital stay was on average 11 74 days the total hospitalization on average 16 96 days (Table 7) The follow-up examination was performed by the research group, personally in 69, by mail in five and according to hospital routine documentation in six cases The total mortality rate was 19 8 per cent (Table 8)

In calculating the results the modified system of Merle D'Aubigne was used for summing up score points for mobility, pain and walking ability However, independently of the total score, if pain was present to any considerable degree the result was classified as one category worse than the total score otherwise indicated (Tables 9 and 10), special attention being paid to early and late complications and also to the classification of reasons of failure other than those belonging to the operated hip joint

Table 6 Features of surgery

Method of anaesthesia	
general	100
epidural	6
Surgeon	
specialist	49
resident surgeon	57
Exposure	
southern	83
Gibson	17
Watson-Jones	1
other	5

Mean duration of operation from the induction of anaesthesia to the extubation 1 h 50 min

RESULTS

The late results after an average time of observation of 40 months were at least satisfactory in 92 7 per cent of the 80 patients whose general condition had remained good enough to permit independent walking and self-care (Table 11) Disability resulting from general diseases and advanced age prevented 11 patients from walking at all, despite good mobility without pain of the operated hip joint (Table 12) The results in the three patients with bilateral arthroplasty were all satisfactory or good

Regarding mobility alone, the goniometric range of movements was able to be recorded exactly in 66 patients The range of active and passive flexion was somewhat less than 90° in seven hip joints and 90° or more in the majority of the Moore joints (Table 13) With respect to pain alone, based on the patient's assessment, it was in two instances so severe that it substantially impaired gait

Regarding walking ability, the major-



*Figure 1 a) Early postoperative dislocation of the Moore head was treated by closed reposition under anaesthesia and immobilisation with plaster spica for 8 weeks
b) No recurrence of dislocation at follow up*

long term movement downwards of the prosthesis This seems to come to a standstill when the prosthetic neck reaches the level of the minor trochanter This was a symptomless phenomenon without any indication of loosening of the fixation

The most serious late problem is inadequate fixation of the prosthesis Lunceford (1965) found it in 0 8 per cent of the operations and Hinchey & Phillip (1964) only in the case of deep infection Loosening of the prosthesis has been the reason for pain leading to reoperation in

Table 1. Late complications (in 80 followed up patients)

Loosening of the prosthesis	2 (2 50 per cent)
Protrusion into acetabulum	3 (3 75 per cent)
Para articular calcifications	8 (10 00 per cent)
Bone resorption around the stem	4 (5 00 per cent)

1 5 per cent of our operations The reason may be that insertion of bone chips into the holes of the stem was neglected, or that there was too large a reaming cavity or some other technical error It has not been possible to trace adequately the mechanism in our two patients

Stability has been achieved after spontaneous bone filling of the stem cavity and reinsertion of the prosthesis with a larger stem This rare complication has not affected the ultimate prognosis Protrusion of the Moore head into the acetabulum is painful but reoperation is not practical If needed, one should reckon with a total hip replacement Radiological evidence of bone resorption around the stem, calcifications in the para articular tissue and the strange almost unnoticeable migration of the prosthesis until its neck settles down against the minor trochanter have seemingly little if any clinical significance

Table 12 Debilitating reasons for inability to walk in followed up bed ridden patients with Moore's prosthesis

Sex	Age	Disease	Mobility score of the hip	Pain score	Gait score
female	61	arthritis rheumatoides	6	6	0
female	59	arthritis rheumatoides	4	6	0
female	84	hemiplegia	6	6	0
male	51	hemiplegia	6	4	0
female	67	parkinsonism	6	6	0
female	70	apoplexia cerebri	4	4	0
male	66	vertigo	5	6	1
female	84	dementia senilis	6	6	0
female	84	dementia senilis	6	5	0
female	85	dementia senilis	5	5	1
female	67	stylus femoris post amputationem	6	6	0

*Table 13 Score at follow up of 66 patients with endoprosthesis**

Score	Mobility score of the hip No of cases	Gait score No of cases	Pain score No of cases
0	–	1	–
1	1	2	–
2	–	2	2
3	1	4	2
4	5	27	14
5	9	10	16
6	50	20	32

* excluding 3 patients with endoprosthesis removal and 11 patients with inability to walk as a result of general disease (Table 12)

Table 14 Intraoperative and early postoperative complications (in 106 cases)

Fracture or fissure of the femur		5
"Superficial" infection		4
"Deep" infection*		3
Luxation of prosthesis		2
Thrombosis		7
Peroneal analysis		1
Deaths		3
Gastrointestinal bleeding	1 month	
Infarctus cordis	4 days	
Embolia pulmonum	1 day	
Decubitis (heel)		1

* in every case prosthesis was removed later

cases did the prosthesis have to be removed and the prognosis was always good In one case malrotation of the prosthesis (anteposition) was noted postoperatively as a result of technical failure (Figure 2)

Occasional cases of superficial infection (3 7 per cent), deep thrombosis (0 9 per cent), decubital ulcer of the heel (3 7 per cent) and peroneal paralysis (0 9 per cent) did not affect the good prognosis

Late complications (Table 15)

Loosening of the prosthesis occurred twice (1 5 per cent) This painful complication always gave rise to re-operation (Figure 3) Protrusion of the Moore head *into the acetabulum was an occasional* radiographic finding (3 7 per cent) Pain seemed to be related to this complication *The simple radiological finding of bone* resorption (5 0 per cent) around the stem was rather symptomless and does not necessarily seem to indicate poor fixation

Calcifications in the soft para-articular tissue (10 0 per cent) could not be correlated with any particular symptoms

In some instances a study of the radiographic sequence shows spontaneous

Hypertrophic overgrowth of osteophytic bone, which is known from the earlier days of Moore operations when arthrotic joints were operated, has not been encountered

DISCUSSION

Overall mortality after osteosynthesis of fresh fractures of the femoral neck is generally high and totals one third of the patients in the sixth year postoperatively (Greenberg et al 1973) This depends on the geriatric condition of the patients operated upon, which is for example also the aetiological reason for fractures of the proximal end of the femur Opinions on this matter are, however, controversial Exceptionally low mortality, morbidity and infection rates are reported after percutaneous Knowles pinnings of fractures of the femoral neck (Arnold et al 1974)

Mortality rates after prosthetic replacement vary widely according to various series reported 14 per cent/6 months (Hinchey & Phillip 1964), 36 per cent/2 years (Hansen & Spotoft 1966), 25 per cent/2 years (Jansen & Hansen 1966), 41 per cent/6 months (Hunter 1969), 26 per cent/4 9 years (Andersson & Nielsen 1972) 11 3 per cent/6 months (Arnold et al 1974) Comparison of series is very difficult and not very meaningful because of large differences in medical and social pecularities

Overall mortality is even said to correspond to that expected in the age group (Andersson & Nielsen 1972) It would perhaps be of value to have some sort of mortality index derived from regional information The 19 per cent mortality in our series during the first 40 months can be compared with an average expected mortality rate for the population of the country as a whole of about 21 per cent calculated from statistical data Primary in hospital mortality in our series (3/109) lies close to that (2/117) in Andersen & Nielsen's (1972) and that (3/132) in Campbell et al's (1960) series Two of our patients died early for reasons probably related to the operative stress, and one after a month of gastrointestinal bleeding of unknown cause Intraoperative mortality should be no problem if preoperative anaesthesiological screening is made routine

Regarding early local problems the most serious complication, which affects the prognosis very unfavourably, is deep infection The incidence seems to be from 1 per cent to 3 per cent of the operations (Campbell et al 1960, Hinchey & Phillip 1964, Danielsson 1965, Lunceford 1965) This is analogous to what we encountered Most often the end result, Girdlestone's pseudarthrosis, has to be accepted Removal of the prosthesis and medical treatment as a rule cures the infection A trial with deep incisions and continuous drainage and massive doses of antibiotics may sometimes be worthwhile, but this treatment should not be prolonged

All other types of usual early complications are prognostically not so bad and can be handled more easily Dislocation of the prosthesis can usually be treated by closed reposition and immobilization with plaster Fractures of the proximal femur can be immobilized without removal of the prosthesis but require prolonged immobilization in plaster without weightbearing until consolidation

Superficial infection, thrombosis and decubital ulcers are not specifically related to this operation and they do not, if properly treated, have any influence on the good prognosis Peroneal paralysis must be taken into account if the southern exposure is used and the surgeon should avoid undue lesions to the ischial nerve

Summarizing the features one could state that Moore's prosthesis 1) eliminates pseudarthroses and necroses of the femoral head with late arthrosis, 2)









Figure 2 a) A case of malinsertion of the stem b) Spontaneous derotation during early vertical ration into the neutral position Good late result

Figure 3 a) The cause of pain in this old female was diagnosed to be loosening of the prosthesis b) After filling stem cavity with bone chips and reinsertion of a Moore head with larger stem good fixation was gained Good late result

Acta orthop scand 47, 79–88, 1976

INTERTROCHANTERIC OSTEOTOMY IN THE TREATMENT OF PERTHES' DISEASE

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Intertrochanteric osteotomy has been carried out in 34 children with Perthes disease Five weeks after the operation the patients were allowed to move about freely The average postoperative follow up period was 27 months At that time the results seemed to be at least as good as those of Thomas' splint therapy The varus derotation osteotomy performed in the initial stage accelerated the process of reossification and seemed to prevent subluxation According to our findings it is worthwhile correcting the subluxation even in cases with irreversible changes

Key words Perthes' disease, venous congestion intertrochanteric osteotomy

Accepted 10 x 75

The most common form of treatment for Legg Perthes Calvé's disease (LPC) in Finland is Thomas' walking caliper If the results were convincing, it would be acceptable to restrict the child s natural need for and joy in movement for 2–3 years which the splint treatment generally requires Since the results are good in barely 50 per cent of the cases (Edgren 1965 Evans 1958, Herndon & Heyman 1952 Karadimas 1971 Mose 1964) and since splint treatment causes muscular atrophy and even leg length discrepancy (Carpenter & Powell 1960, Edgren 1965), it is not surprising that efforts have been made to find a better form of treatment, even in the operative line (Dreyer & Schafer 1974) Axer (1965) has published a material of 12 patients in which the treatment was subtrochanteric osteotomy

In LPC the femoral head "softens" and the most noticeable changes take place anterolaterally In the fragmentation stage, predisposition to subluxation and anteversion of the femoral neck exists The idea of the operation is to make the femoral head articulate well within the acetabulum

Thus, in the active phase the caput is situated as if in a cast, and thus a shape corresponding to that of the acetabulum is preserved during the free movement of the child The caput can be satisfactorily placed inside the acetabulum by varus and internal derotation osteotomy

Our first osteotomy in 1970, on a case with subluxation in the fragmentation stage, was subtrochanteric After that we changed the operative method to intertrochanteric osteotomy since it is technically easy to apply, the re-ossification

permits early weightbearing 3) makes nursing easier and returns the patients to the activities of daily life rather smoothly, 4) avoids cementing risks 5) includes few possibilities of complications which endanger the ultimate favourable results as regards locomotion, and 6) is an operation with wide safety margins for technical errors and serious postoperative morbidity and possibly has no negative influence upon life expectancy, in comparison with the total population

Geriatric traumatology increases in volume Total rehabilitation in old age has to be dealt with in a decentralized manner, i e primarily in regional and municipal institutions, which should also have responsibilities for long term care and treatment of chronic illness

The Moore arthroplasty will more and more be an operation handed over to the general surgeon engaged in treating fresh injuries If mortality and morbidity can be kept within present limits as we are sure they can the indication for operation even in the hands of surgeons less trained than the orthopaedist can be expanded to include most geriatric intra capsular fractures of the femoral neck, except those in patients bedridden as a result of debilitating disorders

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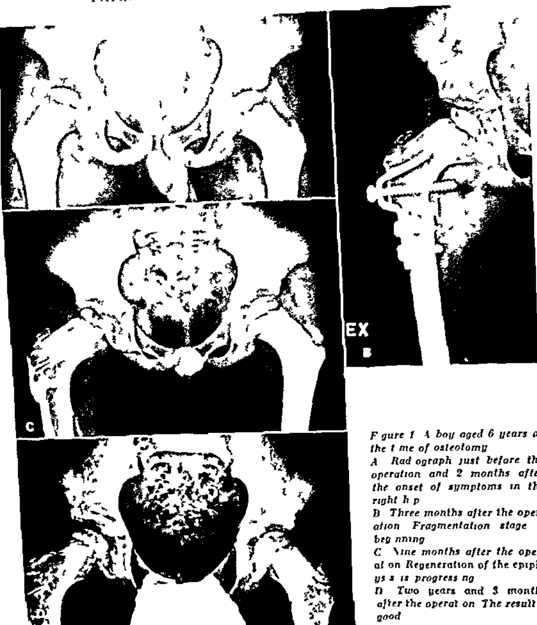


Figure 1 A boy aged 6 years at the time of osteotomy
A Radiograph just before the operation and 2 months after the onset of symptoms in the right hip
B Three months after the operation Fragmentation stage is beginning
C Nine months after the operation Regeneration of the epiphysis is progressing
D Two years and 3 months after the operation The result is good

sessed by the method of Mose (1964) employing the transparent device described by Edgren (1965)

Initial stage

This group included 15 patients The mean period of follow up after the operation was 24 months every case having reached the restitution stage In 12 cases the epiphysis had gone through the fragmentation stage (Figure 1) The mean length of time of this stage was 6 months in the operated patients In three cases definite evidence of fragmentation could not be seen and the initial stage led

is fast, and it gives cosmetically a good result.

SURGICAL PROCEDURE

The degree of varus angulation and derotation required to effect a satisfactory covering was determined *in casu*. In subluxations the angle might be as great as 30°, while in the initial phase 10–15° sufficed. The optimal internal derotation was about 15–25°.

The trochanteric region was exposed from a lateral incision via the posterior fibres of the lateral vastus muscle. A self adapting children's osteotomy plate of 105° by 'Osteon' was used for the fixation. Osteotomy was performed in such a way that first a channel in the collum to accommodate the blade plate was cut with a special seating chisel. The size of the planned varus angulation was observed in the direction of the channel. To define the internal derotation parallel spikes were fixed on each side of the planned osteotomy line.

The femur was cut intertrochanterically and the required internal derotation was made. After this a medially opening wedge equalling the varum was sawn off. The self adapting plate accomplished a stable fixation.

A few days after the operation the hip was immobilized in a plaster cast in the neutral position for a month. The purpose of this cast was to adapt the hip joint to the position of internal derotation to prevent the extremity from turning to a position of external rotation during walking. As early as in the plaster cast phase the child was encouraged to walk and no restrictions were set after the cast had been removed. The plate was removed 3–8 months after the operation.

Table 1. The time interval from the onset of symptoms to the operation

Duration of symptoms (months)	No. of patients	Per cent
0– 3	8	23.5
4– 6	6	17.6
7–11	11	32.4
12–24	2	5.9
> 25	7	20.6
Total	34	100.0

Table 2. Treatment before the operation

		No. of patients
No treatment		18
Thomas splint		16
Duration of treatment (months)	0– 6	3
	7–12	6
	13–24	5
	> 25	2

PATIENTS

During the past two years we have operated upon almost all cases of LPC in the active phase. The material includes those patients who underwent the operation in the period 1970–1973. A total of 34 children were operated upon of whom 30 were boys and 4 were girls. Their mean age at the time of the operation was 7.5 years, the youngest being 5 and the oldest 12 years old. The disease involved the right side in 15 cases and the left side in 19 cases. In five cases the disease was bilateral. However the operation was performed on one side only since the unoperated side had reached the definitive stage. Table 1 shows the time interval from the onset of symptoms to the operation, and Table 2 the treatment before the operation.

RESULTS

The status of the hip of each patient has been followed up on frequent occasions. The results are presented with the patients divided according to the stage of the disease which was present at the time of the operation (Table 3). The stage of the disease was evaluated according to Jonsäter (1953). The results were as

Table 3. The stage of LPC at the time of the operation

Stage	No. of patients	Per cent	No. of cases with subluxation
Initial	15	44.1	–
Fragmentation	10	29.5	2
Restitution	9	26.4	9
Total	34	100.0	11



Figure 3 A boy aged 9 years at the time of osteotomy of the right hip. LPC present for 3 years in the left hip.

A Radiograph just before operation and 3 months after the onset of symptoms in the right hip.

B Six months after the operation. The epiphysis shows the head at risk fragmentation.

C Two years and 5 months after osteotomy. The femoral neck is broad but the shape of the right head is more satisfactory than the left one which is elliptical in shape.



Figure 2 A girl age 1 5 years at the time of osteotomy

A Radiograph just after osteotomy done 4 months after the onset of symptoms Initial stage with condensation of the epiphysis Note rarefaction of the metaphysis

B Six months after the operation Flattening of the epiphysis but no clearly visible fragmentation

C Two years after the operation During the process of the disease fragmentation did not occur The result is good

straight to the restitution stage 2 5 months after the operation (Figure 2)

In every case the femoral head had been moulded into a spherical shape during the restitution stage without subluxation

Case report (Figure 3) The left hip of a 6 year old boy was affected by LPC He was treated with Thomas splint for 2 years When the boy was 9 years old LPC was also diagnosed in the right hip Osteotomy was performed 3 months after the symptoms appeared The fragmentation stage took 3 months whereas the corresponding time on the conservatively treated left side was 14 months

During the process of the disease it was recognised that this case showed evidence of the head at risk (Catterall 1971) In spite of this



Figure 3 A boy aged 9 years at the time of osteotomy of the right hip LPC present for 3 years in the left hip

A Radiograph just before operation and 3 months after the onset of symptoms in the right hip

B Six months after the operation The epiphysis shows the head at first fragmentation

C Two years and 5 months after osteotomy The femoral neck is broad but the shape of the right head is more satisfactory than the left one which is elliptical in shape



Figure 4 A boy aged 8 years at the time of osteotomy He was previously treated for 8 months with Thomas splint

A Ten months after onset of symptoms The epiphysis is flattened fragmented and subluxated

B Five months after the operation The head is not satisfactorily centralized inside acetabulum because the osteotomy has been done with insufficient varus angulation

C Two years after the operation the head is still subluxated and irregular

bad prognostic sign the last roentgenogram (2 5 years after the operation) showed that the right femoral head was being moulded into a spherical shape, whereas the left one was elliptical

In this bilateral case a better result was obtained in the operatively treated hip than in the conservatively treated one, although in the latter the disease manifested itself 3 years earlier It is a generally held view that the earlier the disease appears, the better is the prognosis (Edgren 1964, Mose 1964, Axer et al 1973)

Fragmentation stage

This group was made up of ten cases, two of them also exhibited subluxation The mean postoperative period of observation was 28 months In these cases, a shorter than expected fragmentation stage was observed The mean duration of the fragmentation stage was less than 8 months including both pre- and postoperative periods Every patient had reached the restitution stage and the results were good except in two cases In one of them, the correction of subluxa-



Figure 5 A boy aged 8 years at the time of osteotomy He was previously treated for 15 months with Thomas splint

A Radiograph just before the operation and 18 months from the onset of symptoms Restitution stage with subluxation of the head

B Two months after osteotomy

C Five months after osteotomy The shape of the head is becoming spherical

D Two years after osteotomy The result is good

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tion was not satisfactory as too small a wedge had been removed (Figure 4) In the other case, noticeable osteolytic cavities were observed in the metaphysis The collum remained short and wide and the femoral head somewhat elliptical

Restitution stage

In every one of these nine cases the indication for operation was subluxation The mean period of follow-up after the operation was 32 months In these cases the fragmentation stage had lasted for 14 months during conservative treatment In eight cases as early as a few months after the operation considerable improvement in the shape of the head of the femur was seen (Figure 5) In one case at the time of osteotomy and 3 years after the onset of symptoms, the epiphyseal line was closed and in spite of good centralization satisfactory moulding of the subluxated and irregular femoral head (with a wide and short neck) was not achieved An epiphyseodesis of the greater trochanter was performed in a case where the damage to the capital epiphysis had led to closure of the growth plate with progressive coxa vara deformity

The following case shows that with osteotomy the epiphysis can also be repaired in the late phase if the epiphyseal line is not closed



Figure 6 A boy aged 12 years at the time of osteotomy He was treated for 4 years with Thomas splint

A Radiograph just before the operation

B Subluxation of the head corrected with varus osteotomy

C Ten months after the operation The shape of the head is considerably improved

Case report LPC was diagnosed in the left hip in an 8 year-old *boy* He was treated with Thomas splint for 4 years During this time a marked muscular atrophy developed in the extremity which was 2 5 cm shorter than the other On account of the subluxation the patient was operated upon Within a few months the femoral head became almost spherical In addition *the difference in leg length was reduced to* less than 2 cm

Clinical results

The *operations* were not accompanied by early and late complications Every hip has been painless postoperatively Four patients limped but none had a positive Trendelenburg *sign* A patient treated for 4 years with a splint, had, at the time of operation, a *leg length* discrepancy of 2 5 cm which diminished to 2 cm *Fourteen children had shortening* of the affected extremity of 0 5–1 5 cm and 19 did not have any *discrepancy* at all Every patient could walk and run freely except a boy with a flexion contracture of the hip requiring physiotherapy Most of the patients exhibited some internal derotation which, however seemed to disappear in the course of time

DISCUSSION

With intertrochanteric osteotomy including internal derotation and varus angulation a good and permanent cen

head is an absolute indication for osteotomy The present material showed that it is worthwhile correcting the subluxation even in cases where irreversible changes have already occurred In subluxations the procedure allowed the femoral head to be moulded into a spherical shape within a few months if the capital growth plate was not prematurely closed at the time of the operation

The most satisfactory results have been obtained when the operation has been carried out in the early stage (Axer 1973, Haraldsson 1973) With our osteotomy, performed in the initial stage, the *healing process* was accelerated and subluxation seemed to be prevented Although *according to* Sommerville (1971) osteotomy itself does not speed up the process of *revascularization or of reossification*, the present series definitely shows that this happens In Edgren's (1965) material *the mean length of time* for the fragmentation stage was 10 6 months in patients treated conservatively The present study showed that the mean fragmentation stage took 12 months in those cases in which one hip was treated conservatively or when the operation was carried out in the restitution stage In subjects operated upon in the initial stage, the fragmentation stage was shortened to 6 months on average, and in three cases this stage could not be demonstrated at all as also found by Dreyer & Schäfer (1974) These three cases might have healed in the same way with conservative treatment We feel, however, that by this simple operation the good results were attained with minimum physical restriction of the children

The good results yielded by osteotomy can be partly accounted for by mechanical factors When the caput is well settled within the acetabulum *the weight* bearing surface expands, and because of varum the *strain exerted by the* pelveofemoral musculature on the hip joint decreases *Also Catterall* (1971) has stated that the shearing force would be much less *if the growth plate* were inclined to the horizontal plane, as occurs in varus *osteotomy However*, these factors do not alone explain the shortened *fragmentation stage* and the generally fast and good moulding of the caput Probably there are also other factors such as the effect of osteotomy in the *reparation of hip* arthrosis

Intraosseous venography indicates obstruction *in the* venous *flow* in the initial

and fragmentation stages of LPC (Suramo et al 1974) Obviously these disturbances in the venous circulation hold a central position in the pathogenesis of the disease Osteotomy, performed in the initial stage, improves venous circulation (Heikkinen et al 1976) and accelerates the process of healing even to such an extent that the fragmentation stage possibly does not occur at all

The length of follow-up is so far too short to allow a final evaluation However, even on the basis of the present results, a conclusion can be drawn that no complications have appeared, and that the results seem to be at least as good as those in conservative treatment Operative treatment offers one notable advantage, the child is allowed to move freely 1–2 months after the operation This is an advantage not only for the child but also for the parents, for whom conservative treatment is a considerable burden

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Acta orthop scand 47 89 95 1976

THE EFFECT OF INTERTROCHANTERIC OSTEOTOMY ON THE VENOUS DRAINAGE OF THE FEMORAL NECK IN PERTHES' DISEASE

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Intraosseous femoral neck venography was performed both pre- and postoperatively on 30 patients with Perthes disease At the time of the operation (osteotomy) and the preoperative venographies the disease was in the initial stage in 16 patients in the fragmentation stage in eight patients and in the restitution stage in six patients As shown previously the venous drainage of the femoral neck preoperatively in the initial and fragmentation stages of the disease was different from the venous pattern of the healthy (control) hips in every case indicating an obstruction of the venous flow 4-15 months after the osteotomies this venous obstruction had disappeared completely or almost completely in most cases This normalization happened sooner than expected on the basis of our findings with conservatively treated patients

Key words Perthes disease venous congestion intertrochanteric osteotomy

Accepted 10.x 75

In Legg Perthes-Calve's disease a disturbed venous drainage of the femoral neck, which can be demonstrated by intraosseous venography, occurs both in the initial and the fragmentation stages however in the restitution stage the venographies are the same or almost the same as in healthy hips (Suramo et al 1974)

During the past two years at the Surgical Department of the University of Oulu almost all patients with Perthes' disease have been treated by varus and internal derotation osteotomy (Puranen & Heikkinen 1976) The operative treatment seems to shorten the course of the disease and yield better results than conservative therapy with Thomas' splint (Axer 1965, Dreyer & Schäfer 1974, Puranen & Heikkinen 1976) It could be that the advantageous effect of osteotomy is related to improvement in the venous circulation in the affected area

In the present study intraosseous femoral neck venography was performed both pre- and postoperatively on patients with Perthes' disease On the basis of this investigation attempts were made to obtain information about the effect of osteotomy on the disturbed venous drainage pattern in these patients

and fragmentation stages of LPC (Suramo et al 1974) Obviously these disturbances in the venous circulation hold a central position in the pathogenesis of the disease Osteotomy, performed in the initial stage, improves venous circulation (Heikkinen et al 1976) and accelerates the process of healing even to such an extent that the fragmentation stage possibly does not occur at all

The length of follow-up is so far too short to allow a final evaluation. However, even on the basis of the present results, a conclusion can be drawn that no complications have appeared, and that the results seem to be at least as good as those in conservative treatment Operative treatment offers one notable advantage, the child is allowed to move freely 1–2 months after the operation This is an advantage not only for the child but also for the parents, for whom conservative treatment is a considerable burden

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visualizing of the gluteal vein or veins was accepted as a normal variation

Slightly pathological venography (Figure 2)

In the venographies classified as slightly pathological (+) the contrast medium always flowed to some extent into the diaphyseal area and at the same time one of the extraosseous venous pathways (usually the gluteal veins) was not visualized

Clearly pathological venography (Figure 3 a b)

A venography was clearly pathological (++) if the diaphyseal reflux of the contrast medium was abundant The assessment was the same when the contrast medium flowed to some extent into the diaphyseal area and at least two extraosseous veins were not visualized

Technically unsuccessful venography (Figure 4)

The evaluation of the venous drainage was impossible or uncertain if the contrast medium drained under the periosteum or intra or extracapsularly



Figure 2 A slightly pathological venography The patient was operated at the initial stage 4 months prior to the venography The circumflex veins can be seen but the gluteal vein is not visualized and the contrast medium flows to some extent into the diaphysis

RESULTS

Initial stage (Figure 5 a 5 b)

In the initial stage the preoperative venography was almost always clearly

Table 1 Pre and postoperative venographies of the patients in the initial stage of Perthes disease

Patient	Preoperative venography		First postop venography		Second postop venography	
	Duration of symptoms (months)	Findings	Time from operation (months)	Findings	Time from operation (months)	Findings
1	2	++	4	++		
2	6	+	6	+		
3	3	++	7	+		
4	2	++	6	+		
5	5	+	5	—	18	—
6	3	++	10	—		
7	2	++	6	—		
8	1	++	7	—		
9	4	++	14	—		
10	5	++	6	—		
11	3	++	6	—		
12	5	++	8	—		
13	4	+	12	—		
14	6	+	7	—		
15	2	?	13	—		
16	4	?	9	+	18	+

clearly pathological venous drainage — = normal.
slightly pathological venous drainage ? = technically unsuccessful



Figure 1 Normal intraosseous venographies
A The normal venous drainage of a healthy hip The contrast medium does not flow into the diaphyseal area the lateral and medial circumflex veins and the gluteal vein are clearly visualized
B A normal venous drainage of a hip at the restitution stage of Perthes disease 18 months after the osteotomy All the extraosseous venous pathways can be seen However the contrast medium has spread to some extent into the diaphysis

PATIENTS AND METHODS

The material consisted of 30 patients with Perthes disease The intraosseous venography of the femoral neck was carried out on all patients preoperatively and at least once postoperatively According to the criteria of Jonsater (1953) and Ldgren (1965) the disease was at the time of the operation in the initial stage in 16 patients in the fragmentation stage in eight and in the restitution stage in six patients (Tables 1 2 3)

The postoperative venography was usually carried out in connection with the extraction of the fixation plate However some of the post operative venographies were performed at the Department of Radiology The technique of our venography has been described in detail previously (Suramo et al 1974)

The venographic findings were classified into four groups normal (—) slightly pathological (+) clearly pathological (++) and technically unsuccessful (?)

Normal venography (Figure 1 a b)

According to our previous studies with 90 healthy hips (Suramo et al 1974) we considered the intraosseous venography to be normal if contrast medium injected into the femoral neck flowed out through the lateral and medial circumflex veins and the gluteal veins without or with only a very mild diaphyseal reflux Non

cal venous drainage of the latter patient remained as such also in the second postoperative investigation 18 months after the operation

Fragmentation stage

In the fragmentation stage the patients showed a clearly pathological preoperative venographic finding (Table 2) The duration of the hip symptoms before the preoperative venography was a little more than 10 months (range 8 16 months) The postoperative venographies were normal with the exception of slightly pathological findings in two patients whose venographies were performed 4 and 5 months after the osteotomy In these patients the second postoperative venographies 16 and 17 months after the operation were normal

Restitution stage

In the restitution stage, the preoperative venographies are normal or only slightly pathological (Suramo et al 1974) For this reason the venographic examinations were carried out postoperatively only on some of the surgically treated patients Also in this group a slightly pathological finding seemed to be normalized after the osteotomy, and the normal preoperative venography remained normal also postoperatively



Figure 4 A technically unsuccessful venography The contrast medium has drained intracapsularly

Table 2 Pre and postoperative venographies of the patients in the fragmentation stage of Perthes disease

Patient	Preoperative venography		First postop venography		Second postop venography	
	Duration of symptoms (months)	Findings	Time from operation (months)	Findings	Time from operation (months)	Findings
1	8	++	24	—		
2	9	++	4	+	16	—
3	10	++	5	+	17	—
4	16	++	5	—		
5	9	++	5	?		
6	10	++	15	?	25	—
7	11	++	10	—		
8	9	++	11	—		

++ clearly pathological venous drainage
\+ slightly pathological venous drainage
— = normal.
? = technically unsuccessful.

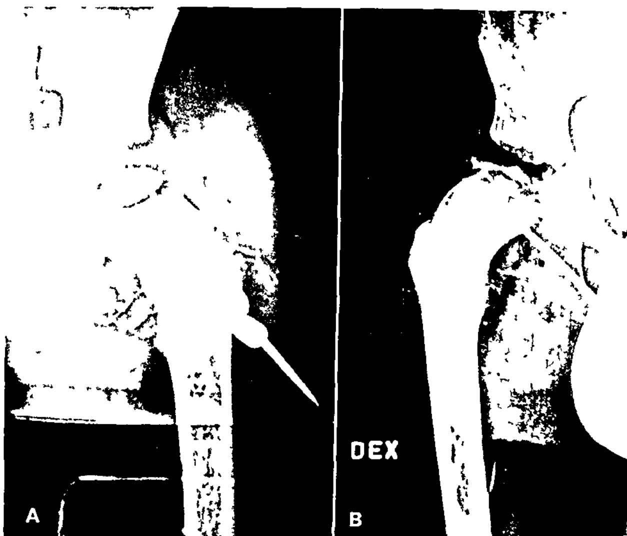


Figure 3 Clearly pathological venographies
A A clearly pathological venous drainage of a hip at the initial stage of Perthes disease The lateral and medial circumflex veins are poorly visualized the gluteal vein fails to show up and the contrast medium spreads abundantly into the diaphysis
B A clearly pathological venous drainage in a hip at the fragmentation stage of Perthes disease All the extraosseous veins cannot be visualized and the contrast medium flows abundantly into the diaphyseal area

pathological (Table 1) Only four out of 16 patients had a slightly pathological finding and two had a technically unsuccessful venography The time interval from the onset of symptoms to the preoperative venography and surgical treatment was, on an average 3 5 months (range 3–6 months) The period between the operation and the first postoperative venography was, on an average, 8 months (range 4–16 months) Thus the time between the onset of the disease and the first postoperative venography averaged nearly 12 months

One patient had a clearly pathological finding 4 months after the operation His pre- and postoperative venographies were similar Five patients had a slightly pathological finding postoperatively Two out of these had a similar venous pattern preoperatively, two had a clearly pathological preoperative venography and one had a technically unsuccessful preoperative venography The slightly pathologi-

neck spread to the diaphyseal area, usually the gluteal and sometimes the medial circumflex veins were not visualized and the contrast medium remained in the bone marrow longer than normal These changes are strongly suggestive of a venous congestion which seemed to decrease during the restitution stage of the disease

The pathological venous drainage in Perthes disease corresponds well with the changes found in intraosseous venography in hip arthrosis (Arnoldi et al 1972) In arthrosis the intraosseous pressure exceeds normal and the effect of the venous circulation on the intraosseous pressure is more important than that of the arterial circulation (Arnoldi et al 1972) Arnoldi et al (1972) have also shown that osteotomy decreases the elevated intraosseous pressure and improves venous circulation in coxarthrosis

Intertrochanteric osteotomies seem to have a favourable effect on the disturbed pattern of venous drainage also in Perthes disease In the patients operated on in the initial stage the venous circulation of the femoral neck was usually normal 8 19 months after the onset of symptoms (Table 1) whereas in those treated conservatively or not treated until the fragmentation stage the preoperative venographies were always clearly pathological 8 16 months after the onset of symptoms (Table 2)

Callus formation at the site of consolidating fractures does not inhibit intraosseous flow of contrast medium (Puranen & Kaski 1974) Therefore a consolidated osteotomy could not block the drainage of contrast medium to the femoral diaphysis and normalize our venograms obtained at least 4 months after the operation

The shortened normalization time of the venous drainage in operated patients corresponds with our clinical and radiological findings regarding a good and fast healing process in Perthes' hip after the osteotomy treatment (Puranen & Heikkinen 1976) Disturbances in the venous circulation probably hold a central position in the pathogenesis of Perthes disease Obviously a poor capillary nutrition results from venous engorgement which seems to occur in the degenerative phases of Perthes disease Whether venous congestion is a cause of the disease or a consequence of it, remains unsolved In any case intertrochanteric osteotomy has a favourable effect on both the venous congestion and the course of the disease

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Figure 5. Case 1?. Preoperative and postoperative venographies (a boy at the age of 7 years). A. Preoperative venography has been taken at the initial stage. The finding is clearly pathological. B. The same hip 8 months after the operation. The venography is normal although the gluteal vein cannot be visualized.

Table 3. Pre- and postoperative venographies of the patients in the restitution stage of Perthes disease

Patient	Preoperative venography		Postoperative venography	
	Duration of symptoms (months)	Findings	Time from operation (months)	Findings
1	24	+	4	—
2	> 24	—	4	—
3	> 24	—		—
4	> 24	+	5	—
5	> 24	—		—
6	> 24	?	7	+

+ = slightly pathological venous drainage   ? = technically unsuccessful
— = normal

DISCUSSION

In the initial and fragmentation stages of Perthes disease the venous drainage of the femoral neck was pathological as reported previously (Suramo et al. 1974). In the pathological venographies the contrast medium injected into the femoral

neck spread to the diaphyseal area, usually the gluteal and sometimes the medial circumflex veins were not visualized and the contrast medium remained in the bone marrow longer than normal These changes are strongly suggestive of a venous congestion which seemed to decrease during the restitution stage of the disease

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Acta orthop scand 47, 96–100 1976

INTRAOSSEOUS PRESSURE IN THE FEMORAL HEAD AND GREATER TROCHANTER BEFORE AND 1–3 YEARS AFTER OSTEOTOMY FOR OSTEOARTHRITIS OF THE HIP JOINT

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To elucidate the long term effect of osteotomy upon the intraosseous pressure in osteoarthritis of the hip, pressure measurements in the femoral head and greater trochanter were performed in 22 patients before intertrochanteric osteotomy and 11 5–33 5 months later, on the occasion of removing the osteosynthesis material after the osteotomy had healed Preoperatively the mean pressure in the femoral head was higher (35 0 mmHg) than in the greater trochanter (23 4 mmHg) At follow up the mean pressure in the femoral head had fallen, but not significantly ($0\ 10 < P < 0\ 20$) A significant reduction in pressure ($0\ 001 < P < 0\ 005$) was found in 10 patients in whom the primary pressure was high (exceeding 35 mmHg) and in 16 patients seen at follow up less than two years after the osteotomy ($0\ 01 < P < 0\ 02$) whereas with a longer observation period there was a tendency towards an increasing pressure The trochanteric pressures accompanied the pressures in the femoral head, but without significant changes No close correlation was found between intraosseous pressure and pain at rest The operation had a good clinical effect, especially upon the pain at rest A reduction in intraosseous hypertension may be a contributory cause, but the tendency to another increase in pressure after a long observation period indicates the possibility of a subsequent recurrence

Key words osteoarthritis, hip joint, intraosseous pressure, femoral head

Accepted 3 ix 75

It has been *demonstrated that in* osteoarthritis of the hip the intraosseous pressure in the femoral head and neck is increased and that presumably there is a correlation between pain at rest in this condition and the intraosseous pressure (Arnoldi et al 1972) Intertrochanteric osteotomy entails an immediate fall of intraosseous pressure (Arnoldi et al *1971), and frequently* an *immediate* disappearance of the pain at rest It is a general surgical experience that as a rule intertrochanteric osteotomy has a favourable effect, also a long time after the osteotomy has healed The long-term effect cannot be explained by the drainage of the medullary cavity during operation

The present study was designed to

compare the pressure findings in the greater trochanter and femoral head in patients with osteoarthritis of the hip immediately before intertrochanteric osteotomy and a long time (1–3 years) after healing had taken place

METHOD

The pressure measurements were carried out immediately before the osteotomy and again prior to removal of the osteosynthesis material after healing of the osteotomy an average of 18.3 (11.5–33.5) months later. During the pressure measurements the patient was under general anaesthesia, lying flat on his back on the operating table. After exposure of the trochanteric region a needle (length 20 cm, lumen 1.20 mm, outer diameter 1.75 mm) was passed under fluoroscopic control so that its tip lay centrally in the femoral head, and a sternal needle (lumen 1.50 mm, outer diameter 2.05 mm) was placed in the greater trochanter. The needles were coupled to pressure transducers (Elema Schonander EMT 35) by polyethylene catheters (length 180 cm, lumen 1.20 mm, outer diameter 2.3 mm), and pressure curves were traced using an electromagnetic writer (Elema Schonander mingograph 81). The level of reference was the central axillary plane. Prior to the pressure measurements the catheters and needles were filled with heparin saline solution. The pressures in the femoral head and in the trochanter were recorded simultaneously and at the same time the patients' systolic and diastolic blood pressures were measured. All the measurements were performed by the authors.

MATERIAL

Primarily the pressure was measured in 24 patients and after healing in 23 as one patient was excluded because of infection and another because of a suspicion of infection. The operative indication was, as is our usual one, we employ intertrochanteric osteotomy mainly for patients having symptoms interfering with their working capacity but without the most severe degrees of restriction of movement or radiological changes. In the most severe cases the treatment is total hip replacement. The patients were included in the material in random sequence depending only upon the authors' presence in the Department.

Table 1 gives the sex ratio and age distribution. All the patients had pain on weightbearing but of extremely varying duration (1–17 years) and 14 had pain at rest. Movements were moderately restricted in all patients, especially flexion and rotation, and all had moderate to severe radiological changes. No patient had decompensated heart disease. A few had hypertension at admission but during the pressure measurements the mean blood pressure exceeded 110 mmHg in only four cases in each of the two measuring series.

Table 1. Sex ratio and age distribution

Number of patients	Men	Women	Age years Mean range
22	14	8	56.5 (41–69)

RESULTS

In Figure 1 the result of the pressure measurements in the femoral head is plotted against the observation period. The values are assessed statistically in Table 2. The mean preoperative pressure in the femoral head was 35.0 mmHg but with a considerable variation of the individual values. At pressure measurement an average of 18.3 (11.5–33.5) months later, the pressures were lower, again with a considerable variation but without any significant decrease in the mean value.

Table 3 shows the corresponding trochanteric pressures. The preoperative mean value was considerably lower than

Table 2. Mean intramedullary pressure in the femoral head in mmHg before (t_1) and after (t_2) intertrochanteric osteotomy and mean individual differences in pressures t_1–t_2. Number of patients 22

	Mean	S.E.	Range
t_1	35.0	3.56	9.2–61.0
t_2	29.3	2.63	4.3–52.0
t_1–t_2	6.7*	4.36	−35.6–55.5

* $0.10 < P < 0.20$ (paired t test)
S.E. = Standard error of the mean

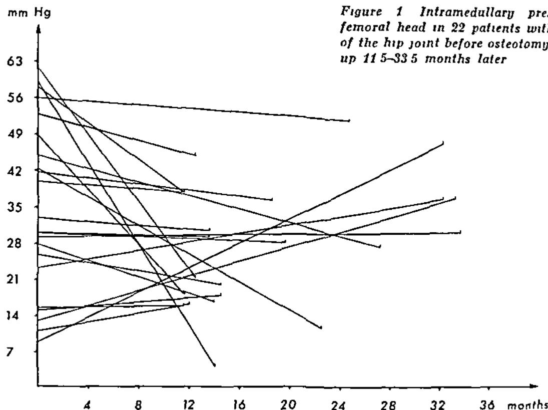


Figure 1 Intramedullary pressures in the femoral head in 22 patients with osteoarthritis of the hip joint before osteotomy and at follow up 11 5–33 5 months later

in the head of the femur There was no significant fall from the former to the latter measurement (This series includes only 21 patients, as the primary pressure measurement in the trochanter was a failure in one case)

Two factors appear to influence the pressure changes demonstrated in the femoral head, viz the preoperative pressure in the femoral head and the observation period Ten patients with a *high preoperative pressure in the femoral head* (> 35 mmHg) exhibited a significant fall after an average observation period of 16 2 (11 5–24 5) months, whereas 12 patients with a *low preoperative pressure* (< 35 mmHg) showed a non-significant increase in the pressure an average of 20 0 (11 5–33 5) months after the osteotomy (Table 4) In 16 patients followed for less than 2 years, average 13 7 (11 5–22 5) months, the mean pressure in the femoral head fell significantly, whereas a non-significant increase occurred in the remaining 6 patients in whom the observation period exceeded 2 years, average 30 7 (24 5–33 5) months (Table 5) However, the comparison is rendered difficult by the latter group being small and including a couple of patients having very low primary pressures

Table 3 Mean intramedullary pressure in the greater trochanter in mmHg before t_1 and after t_2 intertrochanteric osteotomy and mean individual differences in pressures $t_1 - t_2$ Number of patients 21

	Mean	S E	Range
t_1	23 4	2 08	6 8 – 41 0
t_2	21 0	2 62	1 6 – 48 0
$t_1 - t_2$	2 4 *	3 61	– 31 6 – 27 5

* 0 50 < P < 0 60 (paired 't test)
S E = *Standard error of the mean*

Both when classified according to preoperative pressure in the femoral head and by observation period, the trochanteric pressures accompanied the pressures in the femoral heads, showing non-significant changes

The average mean blood pressure of

Table 4 Mean intramedullary pressure in the femoral head in mmHg before t_1 and after, t_2 intertrochanteric osteotomy and mean individual differences of pressures $t_1 - t_2$

A) Preoperative pressure in the femoral head > 35 mmHg
Number of patients 10

	Mean	S.E.	Range
t_1	50.5	2.54	40.0 – 61.0
t_2	29.4	4.81	4.3 – 52.0
$t_1 - t_2$	21.2 *	5.59	1.6 – 55.5

* $0.001 < P < 0.005$ (paired t test)
S.E. = Standard error of the mean

B) Preoperative pressure in the femoral head < 35 mmHg
Number of patients 12

	Mean	S.E.	Range
t_1	22.0	2.51	9.2 – 33.0
t_2	27.4	2.95	15.9 – 47.8
$t_1 - t_2$	– 5.3 *	4.03	– 38.6 – 11.2

$0.20 < P < 0.30$ (paired t test)
S.E. = Standard error of the mean

the 22 patients was somewhat higher (97 mmHg) at the former than at the latter operation (90 mmHg), but the difference was not significant, and there was no correlation between the mean blood pressures and the intraosseous pressures.

The clinical effect of the operation was good with regard to the most annoying symptom of osteoarthritis the pain. Fourteen of the 22 patients had pain at rest before the osteotomy, but only one at follow up. Preoperatively all patients complained of pain on joint movement and on weightbearing. At follow up this pain had disappeared in 8, decreased in 12, while in 2 it was unchanged. However, we found no close correlation between the intraosseous pressure and pain in the individual patient, the mean intraosseous pressure being at the same level whether pain at rest was present or not. Mobility in the hip was unchanged in the group with a short observation period, slightly worse in that with a long observation period. Radiologically the osteoarthritis had decreased a bit (increased width of the joint space) in 6 patients, was unchanged in 15, and slightly worse in 1.

DISCUSSION

The cause of the favourable effect of intertrochanteric osteotomy upon osteoarthritis of the hip has not been finally elucidated, but changes in the vascular conditions around the arthritic joint seem to play a role. Hawk & Shim (1970) emphasized the dependence of the intraosseous pressure upon blood flow, an increased arterial flow and an inhibited venous drainage entailing an increase in the pressure, while reduced arterial flow and improved venous drainage lowered the pressure. Phlebographic studies have demonstrated that the venous drainage

Table 5 Mean intramedullary pressure in the femoral head in mmHg before t_1 and after t_2 intertrochanteric osteotomy and mean individual differences of pressures $t_1 - t_2$

A) Observation period less than 2 years
Number of patients 16

	Mean	S.E.	Range
t_1	37.1	4.04	10.9 – 61.0
t_2	24.4	2.80	4.3 – 45.0
$t_1 - t_2$	12.7 *	4.38	– 5.7 – 55.5

* $0.01 < P < 0.02$ (paired t test)
S.E. = Standard error of the mean

B) Observation period more than 2 years
Number of patients 6

	Mean	S.E.	Range
t_1	29.4	7.43	9.2 – 56.0
t_2	38.8	3.91	27.7 – 52.0
$t_1 - t_2$	– 9.4 *	8.29	– 38.6 – 17.3

* $0.30 < P < 0.40$ (paired t test)
S.E. = Standard error of the mean

is altered and impaired in the arthritic hip (Meriel et al 1955, Phillips 1966, Arnoldi et al 1972), and this agrees with isotope studies (Hernborg 1969) Similar findings were made by Brookes & Helal (1968) in a study of patients with unilateral primary osteoarthritis of the elbow, hip, and knee

Arnoldi et al (1972) also found, in patients with unilateral osteoarthritis of the hip, a higher intraosseous pressure in the affected than in the normal hip and a close correlation between pain at rest and intraosseous pressure By intraosseous injection of contrast medium without anaesthesia, both Phillips (1966) and Arnoldi et al (1972) were able to induce pain of the same nature as the pain at rest in patients with osteoarthritis At intertrochanteric osteotomy the sinusoids of the cancellous bone are drained, and this results in an immediate fall of pressure (Arnoldi et al 1971) As a rule, the pain at rest disappears at the same time

Our investigations did not show any close correlation between intraosseous hypertension and pain at rest, the mean preoperative pressure being the same in patients with and without pain at rest However, we found a significant reduction of the pressure in the femoral head as late as 2 years after the osteotomy, especially in patients with a high primary pressure This decrease in pressure cannot be explained by a difference in arterial pressure in the two series, and it is of a magnitude which cannot be due to differences in central venous pressure Providing an unchanged arterial flow, the fall in pressure must be explained by reduced resistance in the vascular path from the head of the femur to the central veins At phlebography before and about one year after intertrochanteric osteotomy on patients with osteoarthritis of the hip, Phillips et al (1967) did indeed find a normalization of the venous drainage from the femoral head in the majority of those who responded favourably to the osteotomy Similar findings were made by Brookes & Helal (1968) after osteotomy in cases with osteoarthritis of the hip and knee

After a considerable period of time the fall in pressure is possibly again replaced with an increase, and this agrees with the most recent reports on a decreasing subjective effect of osteotomy after a long observation period (Appel & Friberg 1973)

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Acta orthop scand 47, 101–107, 1976

POSTOPERATIVE RESTORATION OF MUSCLE STRENGTH AFTER INTRAMEDULLARY NAILING OF FRACTURES OF THE FEMORAL SHAFT

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The maximal isometric muscle strength of hip abduction, knee extension and knee flexion was measured in 23 patients operated on for femur diaphyseal fractures and fitted with a stable intramedullary Küntscher nail after reaming of the medullary cavity. The trauma, the immobilization and the surgery influenced the musculature of the operated as well as the intact leg. The muscle power recovered in a couple of years but even after 2–6 years a significantly reduced power was found in the knee extensors and a probably significant reduction in the power of the knee flexors in the operated leg when the two legs were compared. Malrotation of the fracture seemed to adversely affect the recovery of muscle power.

Key words: fracture, femur diaphysis, intramedullary nailing, muscle strength

Accepted 10 x 75

The most important aim in the treatment of fractures is to restore the function of the injured extremity to the maximum. The most reliable method of achieving this aim is by active exercise, during the healing process, of as many joints and muscle groups as the fixation methods allow (Charnley 1963, de Palma 1970, Palmer 1962 and others). With suitable diaphyseal fractures of the femur the intramedullary fixation with a thick intramedullary nail gives a fixation stable enough for the extremity to be weight loaded at least partially, before healing of the fracture has taken place (Küntscher 1962, Müller et al. 1969, Böhler 1968). Thus, in connection with a follow-up of a group of patients with diaphyseal fractures of the femur, which were fixed with a stable intramedullary nail (Danckwardt-Lillieström 1973), it was considered to be of interest also to study the recovery of muscle power in the lower extremities. During the healing of the fractures all joints and muscle groups were actively trained in order to provide optimal conditions for the return of muscle power.

MATERIALS AND METHODS

The material consisted of 23 patients, 15 males and 8 females, with an average age of 29 years within the range 15–73 years. Fifteen of the fractures were transverse or short oblique, one

is altered and impaired in the arthritic hip (Meriel et al 1955, Phillips 1966, Arnoldi et al 1972), and this agrees with isotope studies (Hernborg 1969) Similar findings were made by Brookes & Helal (1968) in a study of patients with unilateral primary osteoarthritis of the elbow, hip, and knee

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Table 2 a Total material Observation time 1 to more than 2 years Muscle strength in Kp SD signifies standard deviation of the mean value d mean difference SEM standard error of the mean difference and P significance Comparisons between reference values (Backlund & Nordgren 1969 Asmussen & Heeböll Nielsen 1961) and corresponding intact leg and reference values and corresponding operated leg in hip abduction knee flexion and knee extension

	Reference	Intact leg	d ± SEM	d %	Reference	Op leg	d ± SEM	d %
Hip abduction								
n = 23								
Mean	36.6	33.0	−3.5 ± 1.8	−9.6	36.0	30.6	−5.3 ± 1.6	−14.7
SD	6.7	11.9			6.3	11.0		
P			< 0.05				< 0.001	
Knee flexion								
n 23								
Mean	21.3	21.2	−0.1 ± 1.4	−0.4	21.3	21.1	−3.0 ± 1.1	−12.3
SD	5.3	8.6			5.3	7.8		
P			> 0.05				< 0.01	
Knee extension								
n 23								
Mean	58.2	61.9	3.7 ± 4.4	6.4	58.2	51.1	7.3 ± 4.1	−12.5
SD	7.4	26.8			7.4	24.4		
P			> 0.05				> 0.05	

Table 2 b Comparisons between intact and operated legs

	Intact leg	Op leg	d ± SEM	d %
Hip abduction				
n 23				
Mean	32.3	31.4	−1.9 ± 1.1	5.9
SD	11.7	10.9		
P			> 0.05	
Knee flexion				
n 23				
Mean	24.2	21.1	−3.0 ± 0.9	−12.4
SD	8.6	7.8		
P			< 0.01	
Knee extension				
n 23				
Mean	61.9	51.1	−11.5 ± 2.4	−18.8
SD	26.8	21.0		
P			< 0.001	

were probably significant in all tests (Table 3 a) When the two legs were compared there was a probably significant decrease in the power of the operated leg as regards *knee flexion* and a significant decrease in *knee extension* (Table 3 b)

In patients aged less than 50 years, observed over a period of more than 2 years (group 3 the largest subgroup), there were no significant differences at all in the comparison between the intact and operated legs and their respective reference values (Table 4 a) A comparison between the two legs, however, showed a probably significant reduction of [illegible] as [illegible] ex[illegible]

In patients aged less than 50 years, observed for more than 2 years, with fractures fixed with rotatory displacement (group 3a) there were no significant differences between the muscle power values of the two legs and their reference values In this group, however, the values of the operated legs seemed to be a little lower than the corresponding reference values (Table 5a) A comparison between

Table 1 The material divided into groups according to the observation time and rotatory dislocation

Groups	Observation time (years)	Total number of patients
1 Total material	1 > 2	23
2 < 50 years	1—2	6
3 < 50 years	> 2	14
3a < 50 years (rotatory dislocation)	> 2	5

was oblique, four were comminuted and three were double Twenty of the fractures were situated in the middle third of the femur diaphysis, one in the upper, and two in the lower third Seventeen fractures were treated with an intramedullary nail only, after reaming of the intramedullary cavity, four with a nail and cerclage one with a compression nail and one with a compression nail and cerclage Twenty one fractures were treated with open reduction Seven patients had sustained other serious injuries at the same time, four having fractures of a tibia diaphysis For further details see Danckwardt Lilliestrom (1973) The material has been divided according to age and observation time and also according to other special complications such as rotation deformities (Table 1)

Muscle strength measurements

Measurements of maximal isometric muscle strength during hip abduction knee flexion and knee extension were performed using a technique and equipment described earlier from this hospital (Backlund & Nordgren 1969) A mechanoelectric transducer (Pressductor ASEA, Sweden) was used for the measurements Each test included three maximal efforts, each of a duration of about 3 seconds The highest value recorded in each series was registered Muscle strength values obtained from earlier studies in this hospital (Backlund & Nordgren 1969) and from a study by Asmussen & Heeboll Nielsen (1961) were used as reference values In our laboratory, healthy students of less than 30 years of age contributed to the reference values These are regarded as representative for this age group and the values are also used routinely for patients up to 50 years of age Asmussen & Heeboll Nielsen (1961) used individuals up to 60 years of age and in the present investigation their reference values were used for patients of more than 50 years of age Asmussen & Heeboll Nielsen (1961) used a somewhat different system for muscle strength measurements, i e dynamometers with strain gauges instead of pressductors There is, however, a fairly good agreement between the values obtained from the two materials

Statistics

Standard statistical formulae were used Mean values (Mean), standard deviation of the mean values (SD), mean difference ($\bar{d}$), and standard values of the mean difference (SEM $\bar{d}$) were calculated Student s t test was used for testing the significance and $P > 0.05$ was considered not significant, $P \leq 0.05$ probably significant, $P \leq 0.01$ significant and $P \leq 0.001$ highly significant

RESULTS

Looking at *hip abduction* in the total material there was a probably significant difference between the muscle power values of the intact leg and the reference values and a highly significant difference between the operated leg and the reference values (Table 2 a) However, the numerical differences were small, and when the intact and operated legs were compared, the differences in muscle power were not significant (Table 2 b) As regards *knee flexion* there was a significant difference only in the comparison between the operated leg and the reference value (Table 2 a) Here also, the numerical values were small, but when the operated and intact legs were compared the difference was significant (Table 2 b) There were no significant differences from the reference values for *knee extension* (Table 2 a), but a comparison with the contralateral leg showed a highly significant difference with a numerically quite marked reduction in the value for the operated leg (Table 2b)

In patients aged less than 50 years, with an observation time of 1–2 years (group 2), there were no significant differences between the values of the intact leg and the reference values, whereas the difference between the values of the operated leg and the reference values

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Hip abduction								
n = 23								
Mean	36 6	33 0	-3 5 ± 1 8	-9 6	36 0	30 6	-5 3 ± 1 6	-14 7
SD	6 7	11 9			6.3	11 0		
P			< 0 05				< 0 001	
Knee flexion								
n = 23								
Mean	24.3	24 2	-0 1 ± 1 4	-0 4	24.3	21 1	-3 0 ± 1 1	-12.3
SD	5 3	8 6			5 3	7 8		
P			> 0 05				< 0 01	
Knee extension								
n = 23								
Mean	58 2	61 9	3 7 ± 4 4	6 4	58 2	51 1	7 3 ± 4 1	-12 5
SD	7 4	26 8			7 4	24 4		
P			> 0 05				> 0 05	

Table 2 b Comparisons between intact and operated legs

	Intact leg	Op leg	$\bar{d}$ ± SEM	d %
Hip abduction				
n 23				
Mean	32.3	31 4	-1 9±1 1	-5 9
SD	11 7	10 9		
P			> 0 05	
Knee flexion				
n = 23				
Mean	24 2	21 1	-3 0±0 9	-12 4
SD	8 6	7 8		
P			< 0 01	
Knee extension				
n = 23				
Mean	61 9	51 1	-11.5±2 4	-18 8
SD	26 8	24 0		
P			< 0 001	

were probably significant in all tests (Table 3 a) When the two legs were compared there was a probably significant decrease in the power of the operated leg as regards *knee flexion* and a significant decrease in *knee extension* (Table 3 b)

In patients aged less than 50 years, observed over a period of more than 2 years (group 3 the largest subgroup), there were *no significant* differences at all in the comparison between the intact and operated legs and their respective reference values (Table 4 a) A comparison between the two legs, however, showed a probably significant reduction of *knee flexion* values in the operated leg as well as a significant reduction of *knee extension* values (Table 4 b)

In patients aged less than 50 years, observed for more than 2 years, with fractures fixed with rotatory displacement (group 3a) there were no significant differences between the muscle power values of the two legs and their reference values In this group, however, the values of the operated legs seemed to be a little lower than the corresponding reference values (Table 5a) A comparison between

Table 1 The material divided into groups according to the observation time and rotatory dislocation

Groups	Observation time (years)	Total number of patients
1 Total material	1 > 2	23
2 < 50 years	1 — 2	6
3 < 50 years	> 2	14
3a < 50 years (rotatory dislocation)	> 2	5

was oblique, four were comminuted and three were double Twenty of the fractures were situated in the middle third of the femur diaphysis, one in the upper, and two in the lower third Seventeen fractures were treated with an intramedullary nail only, after reaming of the intramedullary cavity, four with a nail and cerclage one with a compression nail and one with a compression nail and cerclage Twenty one fractures were treated with open reduction Seven patients had sustained other serious injuries at the same time, four having fractures of a tibia diaphysis For further details see Danckwardt Lilliestrom (1973) The material has been divided according to age and observation time and also according to other special complications such as rotation deformities (*Table 1*)

Muscle strength measurements

Measurements of maximal isometric muscle strength during hip abduction, knee flexion and knee extension were performed using a technique and equipment described earlier from this hospital (Backlund & Nordgren 1969) A mechanoelectric transducer (Pressductor, ASEA Sweden) was used for the measurements Each test included three maximal efforts, each of a duration of about 3 seconds The highest value recorded in each series was registered Muscle strength values obtained from earlier studies in this hospital (Backlund & Nordgren 1969) and from a study by Asmussen & Heeböll Nielsen (1961) were used as reference values In our laboratory, healthy students of less than 30 years of age contributed to the reference values These are regarded as representative for this age group and the values are also used routinely for patients up to 50 years of age Asmussen & Heeboll Nielsen (1961) used individuals up to 60 years of age and, in the present investigation their reference values were used for patients of more than 50 years of age Asmussen & Heeboll Nielsen (1961) used a somewhat different system for muscle strength measurements, i e dynamometers with strain gauges instead of press ductors. *There is however, a fairly good agreement* between the values obtained from the two materials

Statistics

Standard statistical formulae were used Mean values (Mean), standard deviation of the mean values (SD), mean difference ($\bar{d}$), and standard values of the mean difference (SEM $\bar{d}$) were calculated Student s t test was used for testing the significance and $P > 0.05$ was considered not significant, $P \leq 0.05$ probably significant, $P \leq 0.01$ significant and $P \leq 0.001$ highly significant

RESULTS

Looking at *hip abduction* in the total material there was a probably significant difference between the muscle power values of the intact leg and the reference values and a highly significant difference between the operated leg and the reference values (Table 2 a) However, the numerical differences were small, and when the intact and operated legs were compared, the differences in muscle power were *not significant* (Table 2 b) As regards *knee flexion* there was a significant difference only in the comparison between the operated leg and the reference value (Table 2 a) Here also, the numerical values were small, but when the operated and intact legs were compared the difference was significant (*Table 2 b*) There were *no significant* differences from the reference values for *knee extension* (Table 2 a), but a comparison with the contralateral leg showed a highly significant difference with a *numerically quite marked reduction* in the value for the operated leg (Table 2b)

In patients aged less than 50 years, with an observation time of 1–2 years (group 2), there were no significant differences between the values of the intact leg and the reference values, whereas the difference between the values of the operated leg and the reference values

Table 4 a Patients aged less than 50 years Observation time more than 2 years Muscle strength expressed in kp Comparisons between reference value and corresponding intact leg and reference value and corresponding operated leg in hip abduction knee flexion and knee extension

	Reference	Intact leg	$\bar{d} \pm$ SEM	$\bar{d}$, %	Reference	Op leg	$\bar{d} \pm$ SEM	$\bar{d}$, %
Hip abduction								
n = 14								
Mean	36.9	37.1	0.3 ± 1.9	0.81	36.8	34.9	−2.0 ± 1.9	−5.4
SD	6.6	10.1			6.0	9.5		
P			> 0.05				> 0.05	
Knee flexion								
n = 14								
Mean	24.4	27.1	2.7 ± 1.7	11.1	24.6	24.6	−0.1 ± 0	−0.4
SD	5.7	7.7			4.9	6.4		
P			> 0.05				> 0.05	
Knee extension								
n = 14								
Mean	58.9	69.4	10.5 ± 5.6	17.8	58.9	60.4	−1.5 ± 4.9	−2.6
SD	26.4	7.4			6.8	23.8		
P			> 0.05				> 0.05	

Table 4 b Comparisons between intact and operated legs

	Intact leg	Op leg	$\bar{d} \pm$ SEM	d, %
Hip abduction				
n = 14				
Mean	37.1	34.9	2.3 ± 1.4	−6.2
SD	10.1	9.5		
P			> 0.05	
Knee flexion				
n = 14				
Mean	27.1	23.7	3.4 ± 1.4	−12.6
SD	7.7	7.0		
P			< 0.05	
Knee extension				
n = 14				
Mean	69.4	60.4	9.0 ± 3.0	−13.0
SD	26.4	23.8		
P			< 0.01	

of the leg can recover after a femoral fracture, if the fracture is treated with an osteosynthesis stable enough to bear weight and is immobilized for as short a time as possible

The results from all these cases indicate that the hip abduction power in the intact leg is more severely affected than other muscle groups studied Likewise, on the operated side, hip abduction is the most affected, but also the knee flexion power is significantly reduced The power of knee extension is numerically reduced to about the same extent, but, because of the wide distribution of the values, it does not appear significant in calculations However, the extension power of the intact leg is very well maintained resulting in the fact that an important and significant difference between the two legs can be registered These results thus indicate that the hip abductors are affected on both sides, while in the operated leg it is mainly the knee extensors, and to a somewhat lesser degree, the knee flexors that show a reduced muscle power 1–6 years after an intramedullary nail has been introduced into a fractured femur

A division of the material into smaller groups gives a better opportunity for analysing the importance, for muscle recovery, of, for instance, the age of the

Table 3 a Patients aged less than 50 years Observation time 1–2 years Muscle strength expressed in kp Comparisons between reference values and corresponding intact leg and reference values and corresponding operated leg in hip abduction, knee flexion and knee extension

	Reference	Intact leg	$\bar{d} \pm$ SEM	$\bar{d}$, %	Reference	Op leg	$\bar{d} \pm$ SEM	$\bar{d}$ %
Hip abduction								
n = 6					n = 8			
Mean	39 2	34 2	−5 0 ± 2 9	−12 8	37 0	30 0	−7 0 ± 2 3	−18 9
SD	5 5	5 6			6 4	8 0		
Range	28–42	27–40			28 42	20–40		
P			> 0 05				< 0 05	
Knee flexion								
n = 6					n = 8			
Mean	26 5	24 7	−1 8 ± 1 4	−6 8	24 8	20 9	−3 9 ± 1 0	−15 7
SD	4 7	1 3			5 3	1 6		
Range	17–29	20–27			17–29	19–23		
P			> 0 05				< 0 05	
Knee extension								
n = 6					n = 8			
Mean	61 8	64 8	3 0 ± 4 4	+ 4 9	59 3	48 1	−10 0 ± 3 2	−16 9
SD	6 3	13 6			7 4	7 8		
Range	49 65	47–82			49–65	39 52		
P			> 0 05				< 0 05	

Table 3 b Comparisons between intact and operated legs

	Intact leg	Op leg	d ± SEM	d, %
Hip abduction				
n = 6				
Mean	34 2	32 8	−1 3 ± 3 3	3 8
SD	5 6	7 1		
Range	27–40	23–40		
P			> 0 05	
Knee flexion				
n = 6				
Mean	24 7	21 3	−3 3 ± 0 8	−13 4
SD	3 3	1 6		
Range	20–29	19–23		
P			< 0 05	
Knee extension				
n = 6				
Mean	64 8	48 0	−16 8 ± 3 7	25 9
SD	13 6	9 0		
Range	47–82	39 63		
P			< 0 01	

the two legs showed no significant differences (Table 5 b)

All patients were able to leave the hospital within one and a half months after surgery At X-ray check after 6 months, all fractures were healed All patients (except two pensioners) had returned to work within 8 months of surgery (average 4 6 months, range 2–8 months) None of the patients had a knee extension defect exceeding 5°

DISCUSSION

The erect position of man is a late acquisition in evolutionary development and hence relatively unstable The muscles in the thigh, especially the quadriceps, which maintain this position, are, therefore, easily deranged by injury to the femur Muscle wasting is rapid and muscle volume is difficult to regain Therefore, it is of interest to know to what extent and how rapidly the muscles

leg was numerically, but not significantly greater than in the reference material This may indicate that the patients had exercised their intact leg powerfully after the accident On the fractured side the muscle power was about the same as in the reference material When the intact and operated legs were compared however it was shown that the knee extension power was significantly lower on the operated side Furthermore the knee flexion power was reduced to about the same extent but with a lower degree of significance Hence the stable osteosynthesis in the medullary cavity seems to create conditions for the recovery of muscle power to practically normal values 2 6 years after surgery even in the operated leg The muscles of the knee joint particularly the extensors of the operated side still did not acquire the same power as those on the intact side In these patients the femur fracture was the predominating injury and the osteosynthesis allowed full weightbearing on the operated leg on an average 1 8 months (range 0 5 5 0) after the operation

With malrotation of the fracture of 10 20° there is a tendency (not significant) for a poorer recovery of muscle power especially knee extension in the operated leg

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Table 5 a Patients aged less than 50 years Observation time more than 2 years Rotatory displacement of the fractured bone ends Comparisons between reference value and corresponding intact leg, and reference value and corresponding operated leg in hip abduction knee flexion and knee extension

	Reference	Intact leg	$\bar{d} \pm$ SEM	$\bar{d}$, %	Reference	Op leg	$\bar{d} \pm$ SEM	d, %
Hip abduction								
n = 5								
Mean	33 8	35 8	2 0 ± 3 9	5 9	33 8	31 8	−2 0 ± 2 2	−5 9
SD	7 1	14 9			7 1	10 5		
Range	28–42	21–57			28–42	20–45		
P			> 0 05				> 0 05	
Knee flexion								
n = 5								
Mean	21 8	22 6	0 8 ± 0 5	3 7	22 2	22 2	−0 2 ± 1 1	−0 9
SD	6 2	5 6			5 9	5 6		
Range	16–29	17–29			16–28	17–31		
P			> 0 05				> 0 05	
Knee extension								
n = 5								
Mean	55 8	51 2	−4 6 ± 8 9	−8 2	55 8	43 2	−12 6 ± 6 4	−22 6
SD	8 0	26 7			8 0	20 7		
Range	49–65	25–90			49–65	18–67		
P			> 0 05				> 0 05	

Table 5 b Comparisons between intact and operated legs

	Intact leg	Op leg	d ±SEM	d, %
Hip abduction				
n = 5				
Mean	35 8	31 8	−4 0±2 1	−11 2
SD	14 9	10 5		
Range	21–57	20–45		
P			> 0 05	
Knee flexion				
n = 5				
Mean	22 6	19 8	−2 8±1 7	−12 4
SD	5 6	8 0		
Range	17–29	16–31		
P			> 0 05	
Knee extension				
n = 5				
Mean	51 2	43 2	−8 0±3 8	−15 6
SD	26 7	20 7		
Range	25–90	18–67		
P			> 0 05	

patient, the length of time since the operation and other special factors connected with the fractures

In the group consisting of young patients with a short observation time, i e 1–2 years, the power of the intact leg was normal, while in the operated leg the power was considerably reduced, especially as regards knee extension Thus the results indicated that a stable fixation with an intramedullary nail allows satisfactory maintenance or a rapid recovery of the muscle power in the intact leg However, the muscle power of the operated leg was not fully restored after 1–2 years, in particular this applied to the power of the quadriceps musculature A factor contributing to the quadriceps being the most affected muscle group is, in all probability, this muscle being most traumatized in connection with the fracture and operation

In young patients, 2–6 years after the accident, the muscle power of the intact

ological types of pseudarthroses among the 21 cases is seen in Table 3. The various radiological types of pseudarthroses found among the 15 cases of congenital pseudarthrosis born in Denmark between 1940 and 1965 are seen from Table 4 (Andersen 1972).

Table 1. Number of patients with congenital tibial pseudarthrosis with and without evidence of neurofibromatosis

	No of patients
Evidence of neurofibromatosis in patient and history of neurofibromatosis in family	7
Evidence of neurofibromatosis in patient but no history of neurofibromatosis in family	5
No evidence of neurofibromatosis in patient or in the family	9
Total	21

Table 2. Cases of congenital tibial pseudarthrosis with and without neurofibromatosis in relation to geographical place of treatment

	No with neuro fibromatosis	No without neuro fibromatosis
Treated in Denmark	6	6
Treated in Chicago	6	3

Table 3. The incidence of neurofibromatosis among the various radiological types of congenital tibial pseudarthrosis

Radiological type of congenital tibial pseudarthrosis	Total no	No with neuro fibromatosis
Dysplastic	8	8
Cystic	5	0
Sclerotic	1	1
Clubfoot	4	0
Pseudarthrosis after osteotomy	3	3

Table 4. Cases of congenital tibial pseudarthrosis born in Denmark between 1940-1965 in relation to radiological type and neurofibromatosis

Radiological type of congenital tibial pseudarthrosis	Total no	No with neuro fibromatosis
Dysplastic	5	5
Cystic	1	0
Sclerotic	1	0
Clubfoot	3	0
Unknown	2	1
Pseudarthrosis after osteotomy	3	3

DISCUSSION

The relationship between congenital pseudarthrosis of the tibia and neurofibromatosis was first noticed by Ducroquet (Ducroquet & Cottard 1939) who found that 10 out of 11 of his patients also showed evidence of neurofibromatosis. This relationship has since been accepted by several authors although the occurrence of neurofibromatosis among cases of congenital pseudarthrosis of the tibia has shown a considerable variation. Van Nes (1966) thus concluded that among 22 patients treated by him there were no cases of neurofibromatosis. In recent articles (Duhaine et al. 1972, Hardinge 1972, Masserman et al. 1974, McBryde & Stelling 1972, Sofield 1971) the percentage has varied from 38 to 70. On the basis of the possible relationship between neurofibromatosis and congenital pseudarthrosis, Aegerter (1950) suggested a relationship between neurofibromatosis and fibrous dysplasia.

The discrepancies in the recorded instances of neurofibromatosis might in some cases be due to inadequate clinical data, but it might also be due to the fact that it is difficult, especially in young children, to establish the diagnosis (Fienman & Yakovac 1970).

In the present investigation it can be seen that in all cases of the so-called

Acta orthop scand 47, 108–111, 1976

CONGENITAL PSEUDARTHROSIS OF THE TIBIA AND NEUROFIBROMATOSIS

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On the basis of 21 cases of congenital pseudarthrosis of the tibia *which were radiologically typed and later personally examined* it was found that all cases of the dysplastic type also showed evidence of neurofibromatosis No evidence of neurofibromatosis was found among the cystic and the clubfoot type of pseudarthroses

Key words congenital, pseudarthrosis, tibia, neurofibromatosis

Accepted 10 x 75

Congenital pseudarthrosis of the tibia seems to be related to neurofibromatosis *In order to establish the relationship,* and if possible to make further distinctions among cases of congenital pseudarthrosis of the tibia the following investigation was carried out

MATERIAL

Congenital pseudarthrosis of the tibia is taken to mean all congenital fractures of the tibia including pseudarthrosis after a pathological fracture or after osteotomy of a lower leg with congenital anterior angulation From cases of congenital pseudarthrosis treated in Danish Orthopaedic Departments and at Shriner s Hospital, Chicago, there were 21 in which a complete series of X-ray films from immediately after birth or prior to the occurrence of fracture were available For all cases complete records from the time of the first treatment were available All 21 patients have later been questioned [illegible] of neurofibromatosis [illegible] was con[illegible]d typical *cafe au lait* spots and had a positive family history of neurofibromatosis In cases where the family history was negative the diagnosis of neurofibromatosis was only considered positive when the child had more than five typical *cafe au lait* spots each of more than 0 5 cm in diameter To obtain a more concise concept of the disease the three cases of pseudarthroses which had occurred after osteotomy were considered separately

RESULTS

Of the 21 patients, 12 had a positive diagnosis of neurofibromatosis (Table 1) In five cases there was no family history of neurofibromatosis but all patients *showed typical cafe au lait* spots and in addition one patient also had multiple tumours of the skin In four of these cases the parents were examined without finding any evidence of neurofibromatosis In the fifth case the patient was adopted and had no knowledge of her family

Of the 12 patients treated in Danish Departments six had a positive diagnosis of neurofibromatosis Of the nine American *patients six had a positive diagnosis* (Table 2) The distribution of the radi-

X ray films because of its dysplastic appearance and its antero lateral bowing

Among the three cases of pseudarthrosis which arose after osteotomy all had a positive diagnosis of neurofibromatosis The X ray films from before the osteotomy showed typical antero lateral bowing but no obvious dysplasia Although it has been stressed previously it should be emphasized that children with congenital antero-lateral bowing of the lower leg and with neurofibromatosis should not have corrective osteotomies unless the indications are very well substantiated and the extremely great risk of pseudarthrosis has been seriously considered

ACKNOWLEDGEMENT

For the permission to use case notes and X ray films I am indebted to
Dr B Eriksen Holstebro Denmark
Dr P Lykke Gregersen Sønderborg Denmark
Dr F Hjalmar Larsen Copenhagen Denmark
Dr N Mouritzen Kolding Denmark
Dr J Saugmann-Jensen Copenhagen Denmark
Dr K Harry Sorensen Odense Denmark
Prof F Thomasen Aarhus Denmark

Aided by a grant from Welanderhjemmenes Fond

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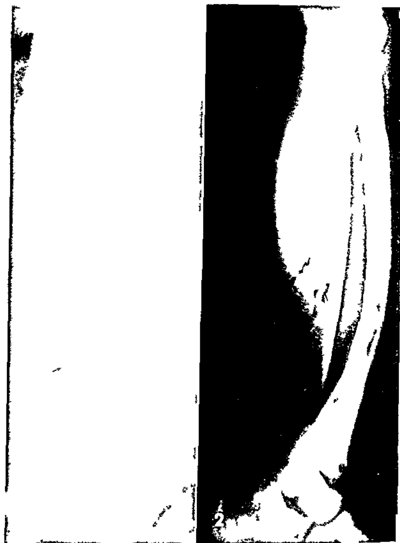
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Figure 1 Dysplastic type of congenital tibial pseudarthrosis before occurrence of fracture

Figure 2 Sclerotic type of congenital tibial pseudarthrosis with pseudarthrosis of the fibula and imminent fracture of the tibia



dysplastic type of congenital pseudarthrosis (Andersen 1973) (Figure 1) a positive diagnosis of neurofibromatosis could be established Among the cystic cases there was no evidence of neurofibromatosis This type is often looked upon as a localized form of fibrous dysplasia As a biopsy has not been routinely performed in the present cases this diagnosis of fibrous dysplasia in the cystic cases could not be confirmed If Aegerter s previously mentioned theory is accepted it would seem that there might exist two types of cystic congenital pseudarthrosis This has not been confirmed so far and the present investigation was also unable to corroborate this view

In the only case of the so called sclerotic type of pseudarthrosis in the present investigation (Figure 2) a positive diagnosis of neurofibromatosis was found As other cases of this type of pseudarthrosis have been seen without any evidence of neurofibromatosis it might be possible that they are not all alike The clubfoot type of pseudarthrosis which has a much more favourable prognosis (Andersen 1973) showed no evidence of neurofibromatosis

The present investigation has thus confirmed that clinically there seems to exist at least three different types of congenital pseudarthrosis The pseudarthrosis connected with neurofibromatosis is easily recognized at the primary

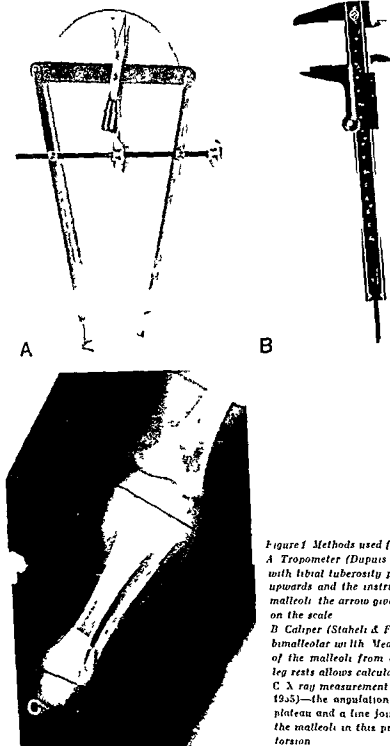


Figure 1 Methods used for measuring torsion
A Tropometer (Dupuis 1951—modified)—with tibial tuberosity pointing directly upwards and the instrument's cups over the malleoli the arrow gives a direct reading on the scale
B Caliper (Staheli & Engel 1977) gives bimalleolar width Measuring the distance of the malleoli from a board on which the leg rests allows calculation of torsion
C X ray measurement (Rosen & Sandick 1955)—the angulation between the tibial plateau and a line joining the tips of the malleoli in this projection gives the leg's torsion

Acta orthop scand 47, 112-117, 1976

TIBIAL TORSION IN UNTREATED CONGENITAL CLUBFOOT

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Current methods of measurement were reassessed by the study of tibial torsion in 1000 normal legs using the tropometer, the caliper and X rays No significant difference in the reproducibility of results was found and the simpler clinical methods appeared to be satisfactory for practical purposes The spontaneous evolution of leg torsion in clubfoot was studied in forty two neglected and previously untreated cases who were seen for the first time after they had begun walking Comparison with the torsion observed in the legs of healthy children of a corresponding age proved that untreated clubfoot is not associated with pathological torsion The place of rotation osteotomy in the treatment of clubfoot is discussed

Key words clubfoot, tibial torsion

Accepted 18 vii 75

It is doubtful if torsion of the tibia occurs more frequently in association with clubfeet than in the legs of healthy children Several authors have assumed that internal tibial torsion occurs in clubfoot This has been reported by Haglund in 1923, Steindler 1950 (as cited by Fripp & Shaw (1967)), and Lelievre in 1961 Wynne-Davies (1964) has reported that no clubfoot patient was found to have a tibial torsion outside the normal range, whereas according to Lloyd-Roberts et al (1974) and Swann et al (1969) pathological external rotation is an important component of the residual deformity in incompletely corrected clubfoot

The correct treatment of clubfoot relies on determination of the direction of torsion The present study has two purposes 1) to find a simple and satisfactory way of measuring tibial torsion for clinical use, from among the many possible methods described in the orthopedic literature, and 2) to determine the torsion of the tibia in a series of neglected and previously untreated clubfeet after the patients have begun walking Settle (1963) studied torsion in embryos and infants, Lloyd-Roberts et al (1974) and Swann et al (1969) studied torsion in treated but uncorrected clubfeet and Wynne-Davies (1964) investigated this factor in patients whose treatment had been completed The clinical material studied by us permits an evaluation of the natural evolution of the torsion of the tibia in cases of clubfoot uninfluenced by treatment In this aspect the present paper differs from any previous publication in this field

Table 1 Tibial torsion measured independently by two observers in 100 normal legs Reproducibility of results

Method of measurement	Average difference in degrees Result of two observers*	Range (in degrees)
Tropometer	3 ± 1	0–8
Caliper	1 5 ± 0 5	0–5
X rays	3 ± 1 2	0–10

* mean ± standard deviation

Table 2 External tibial torsion in normal subjects according to age

Age	No of cases	Mean torsion in degrees*
Under 2 years	20	4 ± 2
2–4 years	23	9 ± 3
4–10 years	35	16 ± 6
Over 10 years	850	16 ± 3

* mean ± standard deviation

cording to age This table confirms the fact that the amount of external rotation is rather small in younger children Beyond 4 years of age external torsion does not increase This table serves as a reference for comparison with the values of tibial torsion observed in clubfeet

All three methods of measurement were used in each case of clubfoot The direction and the degree of torsion found was almost the same whichever method was used Internal rotation of the leg was found in two cases only (less than 5 per cent) In one case the internal rotation was 4 degrees and in the other case 6 degrees

The tibial torsion in clubfeet was compared with that found in the legs of healthy children by pairing the measurement of every affected leg with that of a healthy leg in a child of the same age The average external rotation for the clubfoot cases was 7 5 degrees, whereas the average external rotation in healthy children of corresponding ages was 8 degrees (Table 3) The difference is not significant

In 11 children with a unilateral clubfoot, the average external rotation on the affected side was 8 degrees, whereas the average external rotation on the unaffected side was 11 degrees The difference is not significant

Looking for a possible correlation between the rotation of the leg and forefoot adduction 12 cases with marked adduction (over 60 degrees) were compared with 15 clubfeet where adduction was mild (less than 40 degrees) The mean external rotation in cases with severe adduction of the forefoot was 7 degrees Average external torsion in cases

Table 3 A comparison of tibial torsion in healthy legs and in clubfeet

Average torsion for the age group studied	Healthy children 8 ± 2 5° *	Legs with CTEV 7 5 ± 2 5° *	Average difference 0 5°	Remarks Not significant
Torsion in unilateral clubfoot cases**	Torsion healthy leg 11°	Torsion affected side 8°	3°	Not significant
Tibial torsion related to forefoot adduction	Cases with mild adduction 9°	Cases with severe adduction 7°	2°	Not significant

* mean ± standard deviation
** the group of unilateral cases is too small for calculating the standard deviation
CTEV = congenital talipes equinovarus

MATERIAL AND METHODS

The torsion of the tibia in 100 healthy adults was measured independently by two observers using three methods of measurement in each case (Figure 1 A, B C) These methods were A) the tropometer as described by Dupuis in 1951 B) caliper measurement as described by Staheli & Engel in 1972 C) X ray measurement as described by Rosen & Sandick in 1955 The difference in torsion as measured by the two observers in each case was noted and a statistical evaluation of the reproducibility of the results was possible (Table 1)

After obtaining the results of the study described above torsion was measured in more than 900 legs of healthy individuals using only the tropometer A chart of mean torsion according to age was thus established (Table 2)

Forty two neglected and previously untreated clubfeet were seen by us for the first time after they had begun walking The youngest patient was 2 years old and the oldest was 17 All these cases were quite severe combining varying degrees of varus adduction and equinus The rotation of their legs showed the natural evolution of the syndrome unaffected by previous treatment Tibial torsion was measured by the methods mentioned previously Since it seemed possible that adduction of the forefoot was related to the degree of external rotation at the ankle this parameter was also noted Forefoot adduction was calculated on an antero posterior X ray of the foot by measuring the deviation of the axis of the first metatarsal from a line perpendicular to the base of the cuboid (Figure 2) Values observed in this way denote the combined adduction due to subluxation at the talo navicular joint as well as to metatarsus varus. This method of measurement presents some difficulties in small babies where the cuboid is round but it appeared practical in our hands when measuring adduction in older children after walking had begun Where deformity is most severe and the base of the cuboid unclear the longitudinal axis of the calcaneus may be used as a line of reference Though such a method of measurement is less exact it is quite sufficient for all practical purposes

The values of tibial torsion observed in the clubfeet were compared with those observed in the feet of healthy children of the same age. Tibial torsion was also studied as to its possible correlation with the adduction of the forefoot

RESULTS

Table 1 compares the values of torsion observed by the two physicians using the three methods of measurement It is evident that the method of Staheli & Engel (1972) using the caliper gave the most reproducible results Measurement using X rays by the method of Rosen & Sandick (1955) was not more exact than the simpler clinical methods

Table 2 shows the mean values of tibial torsion observed by us in a large series of normal subjects classified ac

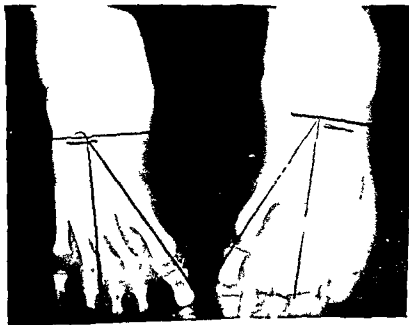


Figure 2 Adduction of the forefoot measured on the antero posterior X ray as the angle of deviation from a line perpendicular to the calcaneo cuboid joint

within the normal range, rotation osteotomy *of the leg has no place in the* primary treatment of this syndrome

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with a mild adduction of the forefoot was 9 degrees The difference is insignificant and the values of torsion correspond to those observed in normal children of the same age group Thus, tibial torsion and forefoot adduction are not correlated

DISCUSSION

There are several publications on precise methods for measuring tibial torsion (Khermosh et al 1971, Mebs & Schrems 1973, Tohno 1973) The method described by Tohno at the 12th congress of SICOT in 1973, using axial tomography, is perhaps the most precise, but is also the most complicated, costly and time consuming Methods like this one must be reserved for theoretical research and have little place in wide-scale clinical screening Some of the simpler clinical methods as reported by Dupuis in 1951 or Weissman in 1954 use the patella as a point of reference, so that the resultant values obtained are a combination of rotation at the knee and torsion of the leg itself We measured tibial torsion using three methods, which seemed most practical for everyday clinical use In our experience, the direction of torsion observed with all three methods of measurement was always the same There were only minor differences in the degree of torsion found in any case, depending on the method of measurement The X-ray measurement described by Rosen & Sandick (1955) is relatively costly and time consuming as compared to the simpler clinical methods and is no more precise As to the two clinical methods tested—the tropometer and the caliper—the main practical difficulty was exact location of the medial malleolus in severely deformed feet of small children This accounted for the difference in values as reported by the two observers The caliper appeared, however, to give more reproducible results and we have adopted it for routine use in our department in the future

The study of tibial torsion in clubfoot has previously been limited to embryos, young babies and children with uncorrected clubfeet or with residual deformities after incomplete treatment Wynne Davies (1964) reviewed 80 cases after completion of treatment Not one of the 110 legs measured by her had a tibial torsion outside the normal range The only difference between the clubfeet and the controls was the tendency for more of the clubfeet to have higher than average lateral torsion According to Lloyd Roberts et al (1974) and Swan et al (1969), the hind foot and ankle mortise of incompletely corrected clubfeet are laterally rotated on a tibia which itself has no rotational deformity Such a rotation is a complication of previous treatment To cite McCauley (1959) "I do not imply that a perfect score could result even from the application of an ideal treatment program, but I am convinced that we who treat these early deformities are responsible for a large proportion of the later and much more perplexing problems"

The present study has shown that the spontaneous evolution of clubfoot is unassociated with a pathological torsion of the tibio-fibular component Lateral rotation osteotomy of the leg masks the adduction of the forefoot, but does not contribute to a "physiological" repair of clubfoot Forefoot adduction has no correlation whatsoever with tibial torsion Medial rotation osteotomy of the tibia has no place in the treatment of neglected clubfoot, but it might be considered for some cases of residual deformities remaining after unsuccessful treatment The latter point was discussed in the paper of Lloyd Roberts et al (1974), where medial rotation osteotomy was advised as a means of helping to bring out the inverted heel Since torsion of the leg in previously untreated clubfoot lies

Table 1 The distribution of Achilles tendon ruptures between the sexes and between sporting injuries and other injuries

	Men	Women	Total
Sport	121	13	134
Other	79	16	95
Total	200	29	229

Table 2 The distribution of Achilles tendon ruptures between the seven sports activities most frequently causing this injury

Badminton	38
Soccer	35
Calisthenics	19
Tennis	15
Hand ball	9
Running	6
Table tennis	5
Others	7
Total	134

RESULTS

The distribution of the cases according to sex and type of injury is shown in Table 1 The sporting activities in which the patients were involved at the time of the injury are listed in Table 2 The annual incidence was calculated in relation to the population of the city (Figure 1) When sports injuries and other injuries were compared (Figure 2) it was clearly demonstrated that the two had different age distributions with different modal values the cases with sports injuries being considerably younger

The observed numbers of Achilles tendon ruptures in the city were compared with the numbers which could be expected from the change in population in the city The increase was significantly greater than expected (Figure 3) This could be demonstrated also for the two subsets sports injuries and other injuries separately (Figures 4 and 5)

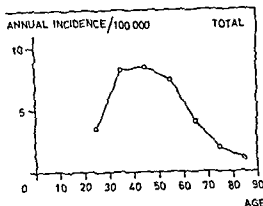


Figure 1 The annual incidence of Achilles tendon rupture in Malmo during the years 1950–1973 total

There was no significant difference between the two with regard to the increase in incidence

DISCUSSION

In a survey of the literature regarding Achilles tendon injury Barfred (1973) and Arner & Lindholm (1959) found a peak value in the latter part of the fourth decade of life Younger as well as older modal ages have been presented Pillet & Albaret (1972) found a bi modal distribution curve according to age The age

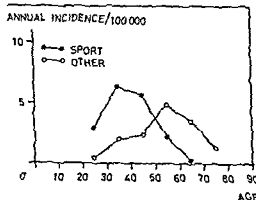


Figure 2 The annual incidence of Achilles tendon rupture in Malmö for the year 1973 shown for sporting injuries and other injuries separately

Acta orthop scand 47, 118–121 1976

THE INCIDENCE OF ACHILLES TENDON RUPTURE

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During the years 1950–1973, 229 cases of Achilles tendon rupture were diagnosed in the city of Malmö More than half of the injuries were caused by sporting activities, the most common being badminton and football (soccer) Ruptures caused by injuries other than sports injuries were found in considerably older subjects During the period investigated the incidence of Achilles tendon rupture increased in the city more than could be accounted for by changes in the population This increase could only be partly explained by the increasing interest in sporting activities in the population at risk

Key words Achilles tendon, rupture, incidence, sporting injury

Accepted 14 vii 75

Many investigators have presented age distributions for rupture of the Achilles tendon So far, however, there is no study in which the age distribution is related to the population at risk so that a true incidence can be calculated Such calculations are of particular interest since it has been suggested (Barfred 1973) that the incidence of the injury is increasing This statement is based on the literature Sets of observations presented in the past (Mayr 1957, Schonbauer 1960, Viernstein 1963, Frings 1969, Freilinger et al 1970, Philadelphy et al 1971) have shown this tendency There is, however, no incidence study which covers a prolonged time period in the same population

The objective of the present study was to calculate the age specific incidence of Achilles tendon rupture in the city of Malmo and to investigate possible changes in this incidence over recent decades

Financial support was obtained from the Swedish Medical Research Council (project no B 75-17X-2737-07 C) and from the Swedish National Sports Association

MATERIAL AND METHODS

Included in this study were all cases of rupture of the Achilles tendon who were diagnosed during the years 1950–1973

Altogether 229 cases were included All the patients were admitted to the Department of Orthopedic Surgery Since the Malmo General Hospital serves a well defined area, the city of Malmo, the Emergency Room and the Orthopedic Department of the hospital receive all cases of ruptured Achilles tendon who get medical attention in this city

The charts were researched with regard to the causal injury The injuries were subdivided into sporting injuries and other injuries and the sports injuries were divided according to the sporting activity during which the rupture occurred All the patients had been operated on

Standard statistical methods were applied Probability levels of 5 per cent or better have been referred to as significant

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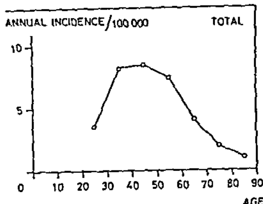


Figure 1 The annual incidence of Achilles tendon rupture in Malmö during the years 1950–1973, total

RESULTS

The distribution of the cases according to sex and type of injury is shown in Table 1 The sporting activities in which the patients were involved at the time of the injury are listed in Table 2 The annual incidence was calculated in relation to the population of the city (Figure 1) When sports injuries and other injuries were compared (Figure 2) it was clearly demonstrated that the two had different age distributions with different modal values, the cases with sports injuries being considerably younger

The observed numbers of Achilles tendon ruptures in the city were compared with the numbers which could be expected from the change in population in the city The increase was significantly greater than expected (Figure 3) This could be demonstrated also for the two subsets, sports injuries and other injuries, separately (Figures 4 and 5) There was no significant difference between the two with regard to the increase in incidence

DISCUSSION

In a survey of the literature regarding Achilles tendon injury Barfred (1973) and Arner & Lindholm (1959) found a peak value in the latter part of the fourth decade of life Younger as well as older modal ages have been presented Pillet & Albaret (1972) found a bi-modal distribution curve according to age The age

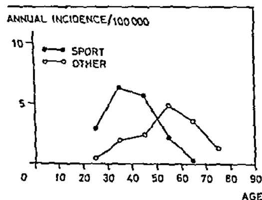


Figure 2 The annual incidence of Achilles tendon rupture in Malmö for the year 1973 shown for sporting injuries and other injuries separately

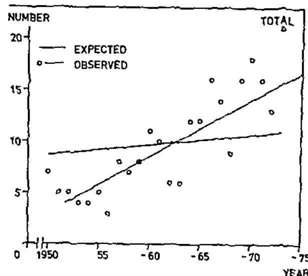


Figure 3 Comparison between the observed change in incidence of Achilles tendon rupture in Malmö during the years 1950–1973 and the expected numbers reflecting the change in population The observed change is represented as the slope calculated from the least squares equation of the annual numbers observed The expected numbers are based on the null hypothesis that no change occurs other than could be accounted for by changes in the size of the population at risk and that the cases are otherwise evenly distributed over the years The slopes are compared by the t test

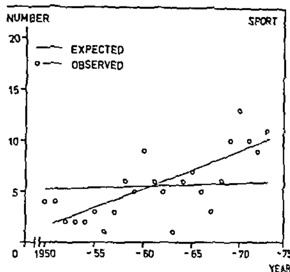


Figure 4 Comparison between the observed change in the incidence of Achilles tendon rupture in Malmö during the years 1950–1973 for sporting injuries only and the expected numbers reflecting the change in population

distribution in our series places it amongst those in the literature with a greater proportion of cases in the older age groups The bi-modal pattern becomes obvious when the injuries are subdivided into sporting and other injuries The younger distribution agrees well with that of Frings (1969) in a study of sporting injuries It should be taken into account that our data are based on a defined population and express incidence rather than frequency Obviously there is a preponderance of cases in the upper middle age group and when the injury is caused by sporting accidents it is more common among older athletes Most athletes active in games and competition are below 30

It is obvious that the risk of having a

Table 3 Enrolment (County of Scania) in sports associations

	1950	1962	1974
Badminton	1,117	1,229	2 833
Soccer	32,166	45 520	60,937
Calisthenics	14,017	22 527	44 030
Tennis	3,248	5 317	8 630

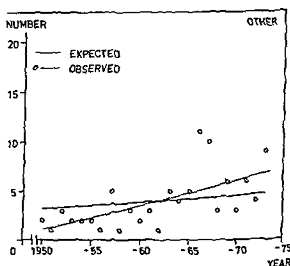


Figure 5 Comparison between the observed change in incidence of Achilles tendon rupture in Malmo during the years 1950–1973 for ruptures not caused by sporting injuries and the expected numbers reflecting the change in population

ruptured Achilles tendon has increased in the city of Malmo during recent decades The increased participation in sporting activities may to some extent be reflected in the enrolment of members in the various sporting associations (The Swedish National Sport Association and the Swedish National Football Association) (Table 3) Insofar as the enrolment reflects the participation in sporting activities in the area the increase in the incidence of rupture of the Achilles tendon is in proportion to the increased participation in the sports most commonly causing this injury

It is much more difficult to explain the increasing incidence of other Achilles tendon ruptures Changes in age distribution have not occurred during the period under study and it cannot be decided whether the change in incidence is due to a decreasing quality of the tendinous tissue of the residents of Malmo or an increased risk of adequate violence

Badminton is a popular sport in Malmo several champions of international accomplishment have been trained in the city This may be one reason for the relatively large number of ruptures in this sport However the people engaged in this sport are outnumbered several times by the tennis players, and, in recent years also by the squash players Badminton seems to involve a special element of risk for the Achilles tendon of the player

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Acta orthop scand 47, 122 124 1976

A COMPARISON OF PLANTAR FLEXION TORQUE WITH AND WITHOUT THE TRICEPS SURAE

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Torque generated about the ankle joints during maximum isometric contraction of the plantar flexor muscles was measured on a subject 4 months after unilateral excision of the entire triceps surae Resulting torque output on the operated limb was 327 kg cm or 38 per cent of the 871 kg cm total for the sound limb

Key words ankle joint exertion muscles, muscle contraction biomechanics

Accepted 18 vii 75

The opportunity to measure and compare the torque output of the plantar flexor muscles with and without the triceps surae rarely presents itself Although the importance of the gastrocnemius soleus muscle group in producing forceful plantar flexion is well recognized, we were unable to find references to comparative measurements of this nature

The purpose of this study is to quantitate the effect of the surgical excision of the gastrocnemius and soleus muscles on the torque generated about the ankle joint during maximum isometric contraction of the plantar flexor muscles of the sound and operated limb of one patient

This investigation was supported in part by the United States Public Health Service Research Grant No 13854 from the National Institute of Arthritis and Metabolic Diseases

METHOD

A 30 year old female with clear cell sarcoma (Enzinger 1965) of the Achilles tendon had surgical excision of the entire gastrocnemius soleus muscle group The remaining leg structures were left intact

The patient began partial weightbearing with crutches 3 days postoperatively and began to walk without assistance 3 weeks after surgery There was no clinical evidence of tumor recurrence and the subject had been ambulatory and leading an active life life for 4 months when the torque measurements were made

During these measurements the subject was supine with her feet over the edge of the testing table and her ankles in the 90 degree or neutral position She held on to the edges of the table and also was stabilized securely on the superior aspect of the shoulders

A cuff was placed around her metatarsal heads and a cable with an attached Liebow® tensiometer was fastened to the cuff with the cable perpendicular to the long axis of her foot She made two attempts at maximum isometric plantar flexion on both the sound and the operated limbs with 1–½ minute rest periods between attempts Her torque output was calculated as the product of the maximum tension

Table 1 *Calculated potential torque of the plantar flexor muscles*

Muscle	Product of physiological cross section (cm²) and absolute muscle force (3 9 kg/cm²)	Lever arm (cm)	Potential torque (kg cm)	Theoretical contribution to total torque	Contribution as calculated from subject
Gastrocnemius	89 7	4 8	430 6	80 %	62 %
Soleus	78 0	4 8	374 4		
Flexor hallucis longus	17 6	2.3	40 4	20 %	38 %
Flexor digitorum longus	*10 9*	2.3	25 1		
Posterior tibialis	22 6	2.3	52 0		
Peroneus longus	16 8	2 6	43 6		
Peroneus brevis	14 8	2 6	38 5		

eter reading and the distance *from the center of* the calf to her ankle joint center (13.3 cm)

RESULTS AND DISCUSSION

The maximum isometric plantar flexion torque of the sound limb was 871 kg cm and that of the operated limb, 327 kg cm (38 per cent of that generated by the sound limb) The maximum contraction *of both limbs occurred* on the second attempt at maximum contraction, and the ratios of the torque produced by the two limbs were similar for both attempts

The total force of muscle contraction cannot be measured directly in the intact body, but assuming static conditions of equilibrium, the product of the transducer force value and the distance between the transducer attachment and the joint center is approximately equal to the product of the rotational component* of the force of the contracting muscles and their lever arms (the perpendicular distance between the action lines of the muscles and the joint centers)

As shown in Table 1, we calculated the hypothetical potential torque of each plantar flexor muscle as the product of its physiological cross section † (Fick 1911), *a factor of 3 9 kg/cm² for absolute* muscle force (Haxton 1944) and the lever arm lengths (Jergesen 1951)

The discrepancy between our actual measurements and the theoretical potential torque calculations (Table 1) may result from several factors The remaining plantar flexor muscles of the operated limb of the patient may have hypertrophied postoperatively *General debilitation* of the plantar flexor muscles of the sound limb during the preoperative and early postoperative period does not appear likely because her sound limb measurements were well above the normal torque measurements of Herman & Bragin (1967) and within the ranges of normal plantar flexor muscle force measurements of other investigators (Clarke 1950, Clarke et al 1950, Liberson et al 1962, Nordgren 1972, Tornvall 1963)

The discrepancy may also result from the physiological cross section sizes and force value used for theoretical torque calculations in Table 1 Since Fick's work in 1911, methods of determining the physiological cross sectional area of a muscle have been developed which correct for the angle of insertion of the muscle fibers into the tendon and for the reduction in size found in cadaver limbs as opposed to live limbs In addition, Haxton's value for absolute muscle force was based on *in vivo* force measurements which were matched with *in vitro* meas-

* The component of the resultant action line of the muscle which is perpendicular to the long axis of the foot

† Cross sections of all of the muscle fibers at right angles to their long axes

urements made from transducers attached on the point of insertion of the tendo calcaneus His experimental design did not account for the torque generated by the five plantar flexor muscles which do not attach to the calcaneus, since he considered that these muscles are at an overwhelming mechanical disadvantage due to the proximity of their tendons to the ankle joint axis

In any event, our actual measurements and the calculated potential torque measurements confirm the importance of the triceps surae in the force of plantar flexion, and yet indicate that the torque generated by the remaining plantar flexor muscles should not be underestimated

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Acta orthop scand 47, 125–128, 1976

THE CALCANEAL OSTEOTOMY OF DWYER: AN INDICATION FOR KIEL BONE

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Kiel bone has been used with uniformly good results as a bone graft in 15 cases of Dwyer's calcaneal osteotomy It is suggested that Kiel bone is indicated for this operation in preference to autogenous bone

Key words talipes equinovarus, calcaneal osteotomy, heterogenous bone graft

Accepted 30 xi 75

Kiel bone is the most widely used preparation of heterogenous bone graft and there have been many, often conflicting, reports of its usefulness since it was introduced It is now evident, from animal experiments and clinical experience, that autogenous bone is generally preferable to heterogenous "Kiel bone" (Baadsgaard 1970, Wilppula & Bakalim 1972) Despite much evidence we believe that Kiel bone is still useful as a grafting material on certain limited occasions, as in children from whom it may be difficult to obtain adequate autogenous bone grafts We suggest that calcaneal wedge osteotomy, performed in talipes equinovarus (Dwyer 1963), is a definite indication for the use of Kiel bone

Dwyer advised that varus deformity of the heel should be corrected by an open wedge osteotomy of the calcaneum and used autogenous bone from the proximal tibia to hold open the medially based wedge A drawback of this procedure is the ensuing weakness at the donor site and we have experience of two children who subsequently sustained fractures of the proximal tibia To avoid this complication we have used Kiel bone and report here on 15 such procedures performed between 1965 and 1972

MATERIAL

The children listed in Table 1 all had congenital talipes equinovarus without any underlying neurological defect In two cases calcaneal osteotomy using Kiel bone was performed on both feet making a total of 15 such procedures in 13 children The initial treatment in these children had usually been by serial plasters and in some of them by subsequent surgical procedures as shown in Table 1

In all cases calcaneal osteotomy was performed on the basis of the criterion suggested by Dwyer, namely a small inverted heel, persisting after the age of three years Operation was performed in a bloodless field, approaching and dividing the calcaneum by a medial incision as described by Dwyer The osteotomy was held open with the heel in a corrected position, using a wedge of cancellous Kiel bone which [illegible]

[illegible] of the tendo calcaneus, performed through

urements made from transducers attached on the point of insertion of the tendo calcaneus His experimental design did not account for the torque generated by the five plantar flexor muscles which do not attach to the calcaneus, since he considered that these muscles are at an overwhelming mechanical disadvantage due to the proximity of their tendons to the ankle joint axis

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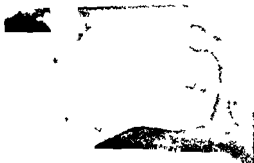


Figure 1 The bone graft 3 months after operation

a separate lateral incision Post operatively the leg was immobilised in a short leg plaster The child was protected from full weightbearing until there was radiological evidence of incorporation of the graft or new bone formation at the osteotomy

RESULTS

The results are also shown in Table 1 Skin healing was frequently delayed and occurred after a mean period of 5 4 weeks (range 2 12 weeks) This compares favourably with skin healing in Dwyer s series and results from difficulty in closure of the often scarred skin The varus deformity has remained well corrected in all cases, except for one subsequently treated by subtalar fusion This procedure does not completely correct forefoot deformity and many cases have slight forefoot adduction



Figure 2 About 1 year after operation the bone graft is partly incorporated into the surrounding bone



Figure 3 After 3 years total incorporation of the graft has occurred

Partial incorporation of the graft as shown radiologically occurred after a mean period of 5 8 months (range 2 24 months) Although no child was immobilised for more than 6 months most of our cases were kept about 12–14 weeks in plaster That is a longer period than those of Dwyer who advises mobilisation after 10 weeks In none of our cases was there radiological evidence of sepsis or rejection of the graft A typical sequence of radiographs is shown in Figures 1 to 3 Complete incorporation of the graft as shown in Figure 3 is a slow process but usually is seen after 2 to 3 years follow up

DISCUSSION

The results of using Kiel bone for osteotomy of the calcaneum compare well with those reported by Dwyer himself for autogenous bone In this series the mean immobilisation period in plaster was 12–14 weeks but probably such a long period of post operative immobilisation is not

Table 1 Age at operation, previous operations and results of calcaneal osteotomy

Case no		Age at operation	Previous operation	Skin healing	Follow up	Partial incorporation radiologically	Comments
1		5 years	None	2 weeks	7 years	2 months	Good result
2		9 years	None	8 weeks	6 years	5 months	Good result but required subsequent lengthening of tendo achilles
3		5 years	Rotation osteotomy of tibia	10 weeks	4 years	3 months	Recurrent equinus deformity
4		5 years	Lengthening tendo calcaneus Rotation osteotomy of tibia	4 weeks	4 years	3 months	Poor result Required sub talar arthrodesis
5	Right	4 years	Lengthening tendo calcaneus	4 weeks	4 years	3 months	Slight forefoot adduction
	Left	4 years	Lengthening tendo calcaneus	6 weeks	4 years	2 months	Slight forefoot adduction
6		3 years	None	2 weeks	1 year	24 months	Good result
7		8 years	Transfer tibialis anterior	2 weeks	3 years	3 months	Good result
8		12 years	Lengthening tendo calcaneus	12 weeks	3 years	6 months	Good result
9		5 years	Lengthening tendo calcaneus Transfer tibialis anterior	2 weeks	3 years	6 months	Slight forefoot adduction
10	Right	4 years	Lengthening tendo calcaneus	2 weeks	3 years	6 months	Slight forefoot adduction
	Left	6 years	Lengthening tendo calcaneus	6 weeks	1 year	6 months	Forefoot adduction and supination
11		10 years	Lengthening tendo calcaneus	6 weeks	2 years	3 months	Slight adduction and supination of forefoot
12		7 years	Lengthening tendo calcaneus Transfer tibialis anterior	4 weeks	1 year	2 months	Good result
13		13 years	None	7 weeks	1 year	12 months	Slight forefoot adduction

Acta orthop scand 47, 129-136, 1976

FINE NEEDLE ASPIRATION BIOPSY IN THE EVALUATION OF TUMOR LIKE LESIONS OF BONE

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A consecutive series of bone lesions suspected to be tumors and examined by fine needle aspiration biopsy at the University Hospital Cytology Laboratory in Lund Sweden is reported From 1966 to November 1974 150 cases were examined In 123 sufficient cellular material was obtained through aspiration by a needle with an outer diameter of 0 8 mm The method is described The reliability of cytology is compared with the results of definite pathology after open biopsy or extirpation of the lesion In the series of primary benign lesions 28 out of 39 were correctly diagnosed among primary malignant 27 out of 38 were correct and among metastases 57 out of 73 were correctly diagnosed including those where insufficient cellular material was aspirated. In cases where sufficient material was achieved the reliability of the cytological diagnosis was around 90 per cent There was one false positive and two false negative reports of malignancy Fine needle aspiration biopsy with cytology is recommended as a standard step in orthopedic oncological examinations It has at least the same degree of diagnostic reliability as other diagnostic methods such as X ray for instance however it does not replace open biopsy and histology when mutilating surgery is in question

Key words biopsy bone tumor cytology differential diagnosis oncology

Accepted 10.x 75

The definite diagnosis of a bone tumor is often a difficult problem and the histologic diagnosis has to be supported by a series of factors such as sex and age of the patient, case history, location of the lesion the roentgenologic appearance, palpable findings and so on It is generally accepted that this analysis is a matter of teamwork in which the orthopedic surgeon the diagnostic and therapeutic radiologist and the pathologist participate Fine needle aspiration biopsy was tested in this diagnostic work as it has a proven value in tumors in other tissues With the thin needles used, 0 8 mm outer diameter, local anesthesia was not necessary, and the procedure was quick and almost painless It could be done ambulatory with very few complications

The first report of needle biopsies in the diagnosis of bone tumors appeared in

necessary In seven out of fifteen cases 2–3 months immobilisation was used without any signs that this time would be too short for safe incorporation of the graft The chief advantage of Kiel bone is to obviate the risk of removing bone from the proximal tibia

Kiel bone is most successful when both the host bone and the graft are cancellous (Hallen 1966) Such conditions occur in calcaneal osteotomy and the radiological appearance suggests that the Kiel bone is acting as something more than just a simple mechanical 'spacer' It is known from animal experiments (Plenk et al 1972) that Kiel bone impregnated with autogenous marrow cells is an effective grafting material It is possible that Kiel bone inserted between the vascular cancellous bone surfaces of the calcaneum becomes rapidly infiltrated by marrow cells and gives rise to a similar preparation Whatever its mode of action, Kiel bone is a successful grafting material in this circumstance and its use prevents the risk of an important complication of this procedure

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Table 1 Correlation between cytologic and histologic diagnoses of bone tumors/bone lesions Lund December 1966–November 1974 150 cases

Histologic diagnosis	Cytologic diagnosis: Primary benign	Suspicion of malignancy	Primary malignant	Metastatic	Suspicion of a metastatic tumor	Insufficient biopsy material	Total
Primary benign	28	1	1	–	1	8	39
Primary malignant	1	2	27	1	1	6	38
Metastatic	1	–	2	57	–	13	73
							150

Primary malignant bone tumors

The cytologic report on 32 cases with a representative yield showed that two cases were misinterpreted as metastases and one as a benign primary bone tumor. It was however possible cytologically to differentiate two main groups of malignant tumors from each other, that is, the osteogenic sarcomas and the round cell sarcomas (Ewing's tumor and malignant lymphomas). Seven of the malignant tumors were chondrosarcomas (Table 2).

Table 2 The cytologic report in seven cases of chondrosarcoma

Chondrosarcoma	2
Chondromatous tumor suspicion of malignancy	2
Cystic fluid—no malignant cells	1
Insufficient material	2

It was possible to identify a chondromatous tumor in four cases but the question of malignancy was very difficult to answer from the smears. The aspirates were sometimes highly cellular with

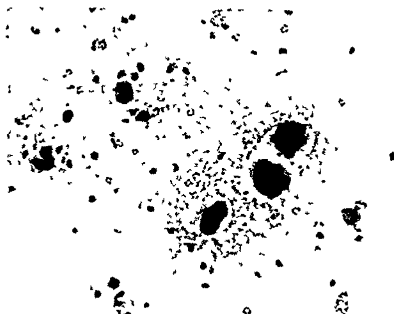


Figure 1 a Aspiration smear from an osteogenic sarcoma. Dispersed polymorphic often multinucleated tumor cells × 160

1930 (Martin & Ellis 1930) Since then several important works have been published (Snyder & Coley 1945, Hajdu & Melamed 1971, Schajowics & Derqui 1968)

All these reports have in common the use of rather thick needles, 18 gauge or thicker (at least an external diameter of 1 25 mm) and this necessitated local anesthesia and often a small skin incision to avoid contamination of the aspirate by surface epithelium With these needles it was often possible to get cellular material both for cytological diagnosis and conventional sectioning and staining, and in Schajowics' analysis of his large material of 4050 cases he stresses the need to combine cytologic and histopathologic examinations

The reliability of this type of bone biopsy was high in the reports, in Snyder s material of 385 cases of primary bone tumors and metastases 82 per cent showed material sufficient for tumor diagnosis and in 67 5 per cent a definite diagnosis was possible Only one false positive diagnosis was made

The fine needle aspiration biopsy, as compared with the above mentioned biopsy method, is simpler, quicker and kinder to the patient but if this type of needle biopsy is to be of value the cytologist must be able to differentiate primary bone tumors from metastases and to separate the malignant primary bone tumors from the benign tumors and lesions A preliminary report of cytodiagnosis of bone lesions by means of fine needle biopsy has been published by Stormby & Åkerman (1973)

MATERIAL

The primary histopathological diagnoses were revised by one of us (Berg) The primary cytologic reports were also revised but no change was made in interpretation The original report was compared with the final report of the histopathological revision

This material includes all bone tumors or lesions examined by cytology but not every tumor case treated at the Orthopedic Clinic during the period under discussion Between 1966–1970 the orthopedic surgeon responsible for the case decided if a needle biopsy should be performed but in 1970 a special orthopedic oncology team was established for evaluating the bone tumor cases (orthopedic surgeon diagnostic and therapeutic radiologist cytologist pathologist and in special cases additional specialists) Each week the tumor cases referred to the group were examined and discussed and needle biopsy considered If angiography was decided upon the needle biopsy was postponed until after the angiography the other cases were biopsied immediately and the next step in the diagnostic analysis decided upon on the basis of the cytology report The time interval between the needle biopsy and the subsequent surgical intervention varied between 3 days and 1 week

The aspirates were examined by all together eight different cytologists during the years and the analysis represents the reliability of the cytodiagnostic method used as a routine procedure

METHOD

Almost all the biopsies were performed by the cytologist in the same way as for non osseous lesions

Thus all the punctures were made with a special holder for disposable plastic syringes The outer diameter of the needle was 0 7 or 0 8 mm and its length varied between 25 and 80 mm In cases with a palpable tumor the aspiration was made according to the palpatory findings In the other cases the sites for the biopsies were chosen on the basis of the roentgenogram and some lesions especially those in the vertebrae were punctured during X ray translumination with TV amplifier The aspirates were spread as a conventional blood smear and as a rule fixed in 95 per cent ethanol before staining with hematoxylin eosin In a majority of the cases however some slides were also air dried and stained according to May Grunwald Giemsa With the eosin stain it was possible to get a stained smear in less than 10 minutes and rapid reports were possible

RESULTS

With the fine needle it was possible to get sufficient cellular material in 123 of the 150 cases (Table 1)

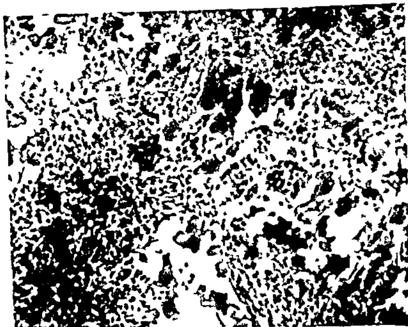


Figure 2 a
The cellular aspirate from a giant cell tumor Numerous giant cells and sheets of mesenchymal tissue × 160

liters of thick yellow brown fluid in the smears thick clusters of cellular debris polymorphonuclear leukocytes and macrophages were found

In the cases which proved to be metastatic the fine needle biopsies succeeded in 60 cases out of 73 (Table 1) There was one false negative report Two cases were considered as primary malignant bone tumors instead of metastatic (cases 3 and 8 in Table 3) In 14 patients the metastatic bone lesion was the first sign

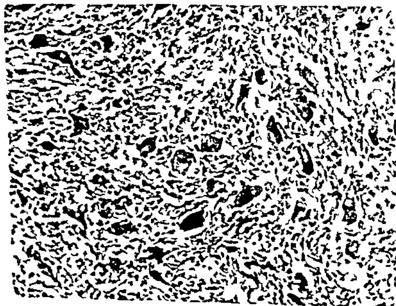


Figure 2 b
Histologic section from the same giant-cell tumor × 160



Figure 1 b Histologic biopsy from the same case of osteogenic sarcoma as in Figure 1 a × 160

atypical and multinucleated chondrocytes but in other cases poor in cells and with no apparent atypia

The aspirates from the osteosarcomas (12 cases) showed a rather uniform picture of pleomorphic tumor cells with multinucleated tumor giant cells, mitosis often atypical and in some cases clumps or strands of a homogenous material surrounding groups of tumor cells This material was probably osteoid

In Ewing s sarcomas and malignant lymphomas the cells were more uniform, no giant cells were present and the cytoplasm was rather sparse The cells showed a strong tendency for dissociation, occasionally small rosette like cell groups were seen in Ewing s tumor

Primary benign tumors/lesions

Of the 39 primary benign tumors or lesions it was possible to penetrate the corticalis and to get adequate cellular material in 31 cases

One case was misinterpreted as a malignant tumor It was a large chondromyxoidfibroma in the sacrum later locally resected This false positive report shows, as in the chondrosarcoma cases, the difficulty involved in differentiating between malignant and benign chondromatous tumors

Among the benign lesions belonging to 'the giant-cell group" were six giant cell tumors, two reparative granulomas in the mandible, one osteoblastoma and one case of hyperparathyreoidism These various types showed similar aspirates multiple giant cells with several crowded nuclei and between them clusters of mesenchymal cells with rounded or oblong nuclei and indistinct cytoplasm Without knowledge of the tumor site, roentgenologic findings and the age of the patient it was only possible to report a benign tumor belonging to the "giant cell-group The giant cell tumors at the end of the long bones have very characteristic roentgenologic signs, however, and in this location a definite diagnosis of giant cell tumor is possible No giant cell tumor was considered malignant in the cytologic report

In the five osteomyelitis cases the aspirates were often pus like, a few milli-

The cytologic misinterpretations are listed in Table 3 Two cases of chordomas (cases 5 and 8) were supposed to be metastases When re-analyzing the smears it was possible to identify the mucoid material and the physaliphorous cells in case 8 in the Giemsa stained smear In the other case only hematoxylin eosin stained smears were available It is probably impossible to differentiate a leiomyosarcoma metastasis from a primary bone sarcoma (case 6) The primary tumor had not been discovered at the time of the needle biopsy In cases 1 and 2 the reevaluation of the aspirates showed a very scanty cellular material and in these cases it would have been better to report that insufficient material was available

The fine needle technique described here seems therefore to be as adequate as when a thicker needle is utilized and in addition anesthesia is not needed and the local bleeding is reduced There were no immediate complications such as pain hemorrhage or infection after the needle aspirations and no signs of local metastases were ever observed in the puncture canal

The purpose of using a biopsy method with a total reliability of approximately 70 per cent (including the cases where the aspiration failed to give material) must be compared with the risk costs and pain involved In bone lesions physical findings and X ray findings including angiography and scintigraphy if utilized all have a limited diagnostic reliability but give important contributions when the question of operability and operative technique arises Puncture cytology of the type described here is therefore a standard step in our examination of bone lesions at the Center of Orthopedic Oncology It is used as a guiding influence in some cases leading to unsuspected alternatives but it is only exceptionally used as a basis for radiotherapy without an open biopsy and never for mutilating surgery such as amputation In locations where a local extirpation is possible without mutilation consequences it may be regarded as giving sufficient information

The chondromatous group seems to be the most difficult to subspecify by this technique When a chondromatous tumor is suggested by X ray and cytology an extirpation of the tumor *en bloc* is curative if benignity is confirmed by histology and adequate as a biopsy if not In some cases a ganglion like liquid has induced us to inject X ray contrast in order to map out the cavity One of these turned out to be a chondrosarcoma with a large cystic center, however

Cytology should not be omitted because it is only 70 per cent conclusive as it is more reliable than many other diagnostic measures in these cases and the method as reported here is rapid pain free and of little risk and thus appealing At surgery the canal is removed *en bloc* if possible The vertebral biopsies are of special interest (Table 4) Here cytology is as reliable as in other locations and open biopsy is often more troublesome In general metastases are relatively more common in vertebral locations Cytology is therefore almost indispensable in such cases if there are no signs of medullary compression which would indicate the need for an operative intervention

The reliability of cytology compared with histology in this series depends on the experience of the cytological laboratory As with bone pathology in general considerable experience is necessary for safe microscopic diagnoses to be made

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Table 3 Details of eight cases in which cytology was misinterpreted There were 123/150 cases with sufficient cellular material

Case	Year	Cytology	Histology
1	1970	Primary benign	Metastasis from renal carcinoma
2	1971	Benign	Sarcoma
3	1971	Suspicion of a metastasis	Fibrous dysplasia
4	1972	Primary malignant	Metastasis from epidermoid carcinoma
5	1972	Metastasis Renal carcinoma?	Chordoma
6	1973	Primary sarcoma	Metastasis from uterine leiomyosarcoma
7	1973	Chondrosarcoma	Chondromyxoidfibroma
8	1974	Metastasis from adenocarcinoma	Chordoma

of a malignant tumor The cytology was able to suggest the site of the primary tumor in 6 cases Vertebral lesions were as reliably diagnosed from cytology as were other lesions (Table 4)

DISCUSSION

Bone lesions in general are not expected to be accessible through a fine needle and a needle biopsy of bone tissue is perhaps expected to yield an insufficient volume of material for a diagnosis, which might be debatable even with conventional sections after fixation and decalcification

This consecutive series with fine needle cytology compared with final histology shows that 123 out of 150 bone lesions yielded sufficient material for a diagnosis This means 82 per cent and compared with Snyder & Cooley s (1945) series with thicker needles this figure is identical If the accessibility with our fine needles seems therefore to be adequate what about the reliability? In Snyder's series 67 5 per cent gave a correct definite diagnosis and in 82 per cent a definite tumor diagnosis was made In our series the diagnosis was correct in 72 per cent among the primary benign, 71 per cent in primary malignant and 78 per cent in metastatic lesions In the lesions with sufficient cellular material it was possible to differentiate primary bone lesions from metastases in 90 per cent and primary benign tumors/lesions from primary malignant tumors in 95 per cent

Table 4 Details regarding 14 vertebral lesions

Site	Cytology	Histology
L V	Myeloma	Myeloma
C IV	Myeloma	Myeloma
Th XII	Myeloma	Myeloma
Th XII	Sarcoma	Sarcoma
L II	Chondromatous tumor	Chondrosarcoma
Th XII	Metastasis adenocarcinoma?	Chordoma
C IV	Primary bone tumor osteoblastoma?	Giant cell tumor
L IV	Metastasis adenocarcinoma	Metastasis adenocarcinoma
Th IV	Metastasis	Metastasis
L III	Primary benign	Metastasis renal carcinoma
L II	Metastasis	Primary hepatocellular carcinoma
L III	Metastasis adenocarcinoma	Primary carcinoma of the colon
L II	Metastasis hepatocellular carcinoma?	Primary hepatocellular carcinoma
L III	Insufficient material	Metastasis from an adenocarcinoma

Acta orthop scand 47, 137–143, 1976

07

FINE NEEDLE ASPIRATION BIOPSY OF BONE LESIONS: CLINICAL VALUE

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The clinical value of cytological aspiration biopsy in 85 patients with lytic bone lesions was studied In 71 cases cytology was of diagnostic value, but in 14 cases it was inconclusive or misleading The method is considered a simple primary diagnostic procedure especially in lytic bone lesions of uncertain nature

Key words metastases, cytodiagnosis, aspiration biopsy, fine needle aspiration

Accepted 23 x 75

Fine needle aspiration biopsy is well known as a safe diagnostic procedure and has been used in investigations of various organs for many years However, aspiration biopsy of bone lesions has not been generally accepted, except in a few centres, where great experience has been gained (Hajdu & Melamed 1971, Ottolenghi 1955, Schajowicz 1955, Schajowicz & Derqui 1968, Snyder & Coley 1954 and Stormby & Akerman 1973) For the past two years this method has been used in our institution and the purpose of this preliminary study has been to evaluate its significance in clinical work

MATERIAL AND METHODS

Eighty five patients the majority with *lytic* bone lesions seen on X ray, were referred for fine needle aspiration biopsy from various clinical departments (Municipal Hospital and Orthopaedic Hospital Aarhus)

All punctures were carried out in the X ray Department under fluoroscopic monitoring After local anaesthesia in adults and as a rule universal anaesthesia in infants a needle with an outer diameter of 0 9 mm equipped with an obturator was inserted into the lesion and, after withdrawal of the obturator, aspiration biopsy was performed through this needle by means of a finer needle (diameter 0 6 mm) Several aspirations were carried out and the material obtained was then placed on one or several slides and smears were made These were air dried and stained according to the May Grün wald Giemsa method

Where necessary, material collected was set apart for bacteriological examination

All slides were revised and compared with the primary cytological reports All clinical notes, autopsy reports and available histological material were reviewed

The cytological diagnoses were verified in the following manner

1 Tissue sections from the same lesion
2 In patients with a known primary tumour, tumour cells in the slides were generally accepted as representing metastases from that tumour
3 In patients with an unknown primary tumour or apparently successfully treated primary tumour the clinical course including

biopsy in lesions of the locomotor system Review of results in 4050 cases including 941 vertebral punctures *Cancer (Philad)* 21 523 541
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4 Misleading true false positive or negative reports

RESULTS

The anatomical sites of the punctured bone lesions are given in Table 1 Thirty-seven lesions were located in the spine or pelvis including eight in the dorsal spine

Table 1 Punctured lesions

Column	cervical	1
	thoracic	8
	lumbar	11
Pelvis		17
Chest		13
Extremities		35

Primary cytological reports and the results of the revision of slides, compared with the clinical diagnoses, are given in Table 2 Miscellaneous comprises spondylitis, arthritis and other cases The specimens often contained only a few osteoclasts or osteoblasts or some leucocytes and other cells from the reticulo-endothelial system (Figure 2) The verification of the cytological diagnoses is given in Table 3 Histological verification was obtained at autopsy in 8 cases, by surgical biopsy in 7 cases and by drill biopsy in 13 cases

In 24 cases of metastases the primary malignant tumour was verified during

Table 2 The primary and revised cytological reports are compared with primary clinical diagnoses in patients subjected to aspiration biopsy Figures in brackets indicate false positive and negative reports

Diagnosis 85 patients Lesion			Primary cytological reports		Revision	
			Benign	Malignant	Benign	Malignant
Primary	benign	13	9	(4)	13	0
	malignant	12	(1)	11	(1)	11
Metastases		43	(9)	34	(8)	35
Miscellaneous		17	17		17	



Figure 2 . . . . cells (e) .

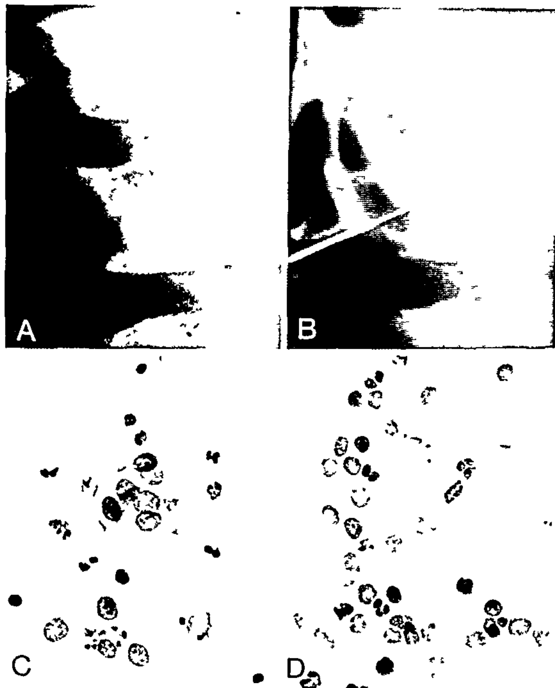


Figure 1 A 5 year old girl previously treated for an angiosarcoma on the back now complaining of lower back pain A Lytic and expansile lesion in the first lumbar segment also involving the pedicles B Aspiration biopsy of the lesion C Cells from the lesion were erroneously diagnosed as sarcoma cells but later found to be cells from histiocytosis X D Smear from a typical case of histiocytosis X The cells are quite similar to those illustrated in C One year later spontaneous restoration of the first lumbar segment

X ray findings laboratory tests and clinical examinations was used as verification

4 Finally there were a few cases with no follow up

The clinical significance was evaluated according to the following four groups

1 Decisive leading directly to further diagnostic or therapeutic procedures
2 Supportive supporting but not changing the clinical diagnosis
3 Inconclusive no material or no malignant cells in the slides when malignancy was strongly suspected

4 Misleading true false positive or negative reports

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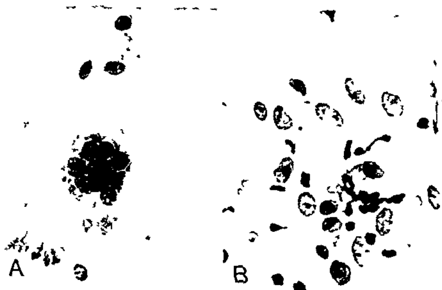


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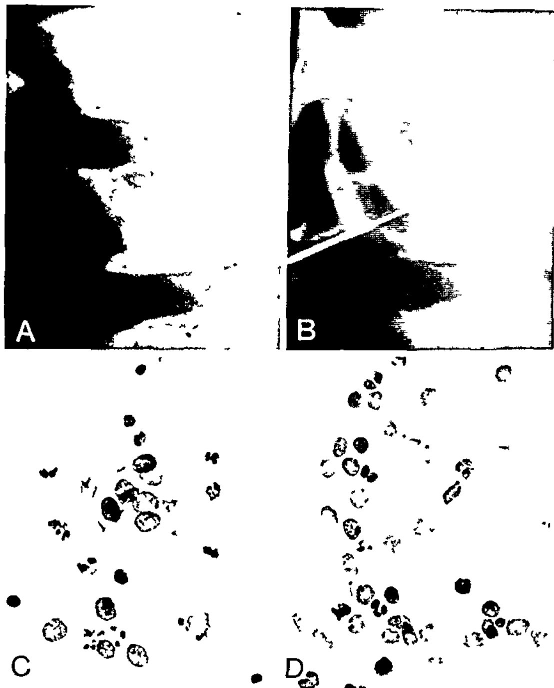


Figure 1 A 5 year old girl previously treated for an angiosarcoma on the back now complaining of lower back pain A Lytic and expansile lesion in the first lumbar segment also involving the pedicles B Aspiration biopsy of the lesion C Cells from the lesion were erroneously diagnosed as sarcoma cells but later found to be cells from histiocytosis X D Smear from a typical case of histiocytosis X The cells are quite similar to those illustrated in C One year later spontaneous restoration of the first lumbar segment

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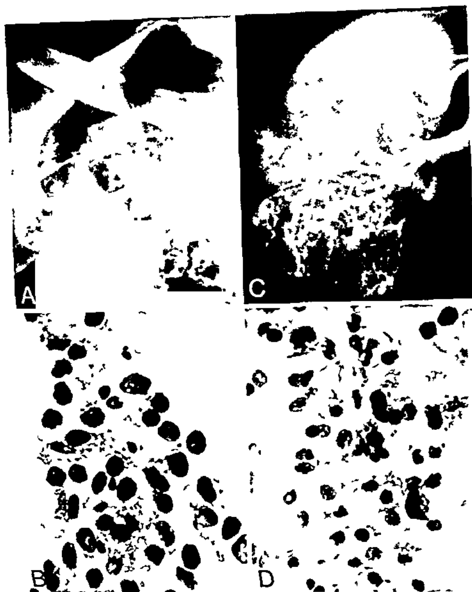


Figure 4 70 year old man with pain in the right first rib A X ray showed expansile osteolytic lesión in the right first rib suggesting chondroma or chondrosarcoma B Aspiration biopsy from the lesion in the first rib revealed hypernephroma cells C Angiography 1 week later showed malignant tumour in the right kidney D Aspiration from the renal lesion showed hypernephroma cells Operation confirmed the diagnosis

hospitalization The 28 cases, where the clinical course was used included patients with both malignant and benign diseases Finally in five cases follow up was not possible

The clinical value of the primary cytological reports is given in Table 4

Decisive These included patients with myeloma and cases of metastases where the cytological report led directly to the

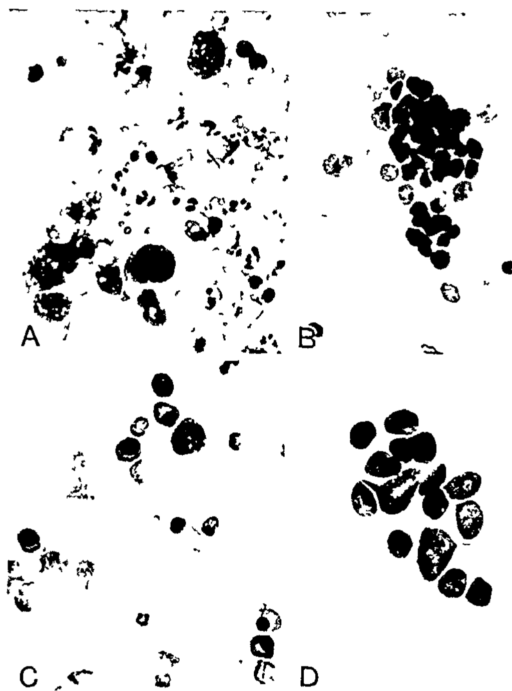


Figure 3. *A. Smear from a case of osteogenic sarcoma. Isolated highly malignant cells with huge nucleoli. B. Smear from a case of Ewing's sarcoma. Cluster of small highly malignant cells with scanty cytoplasma. C. A typical case of plasma cell myeloma. D. Carcinoma cells from metastasing mammary carcinoma.*

Table 3. *Verification*

Histology	28
Known primary tumour	24
Clinical course	28
No follow up	5

Table 4. *Clinical value*

Decisive	19
Supportive	52
Inconclusive	7
Misleading	7

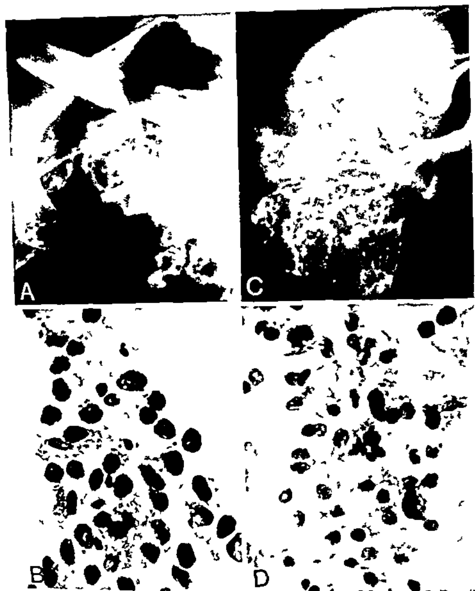


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The clinical value of the primary cytological reports is given in Table 4

Decisive These included patients with myeloma and cases of metastases where the cytological report led directly to the

primary tumour (Figures 3, 4) Cases where treatment was based on the cytological report only were also included Finally, aspirations from the spine where bacterial cultures were positive

Supportive These included cases with a known primary tumour with some lesions strongly suggestive of metastases, with carcinoma cells in the aspirates The majority of the miscellaneous cases were also included in this group

Inconclusive These comprised specimens with insufficient material to support a diagnosis

Misleading There were four false positive and one false negative reports from primary tumours and two false negative reports from metastases

No severe complications occurred, however, one patient developed pneumothorax a few hours after puncture of the dorsal spine

DISCUSSION

The advantages and disadvantages of fine needle aspiration biopsy have been discussed in many papers and will not be discussed further However, it must be emphasized that by using this method with a larger needle equipped with an obturator we have minimized the chances of missing the target This justifies the consideration of even scanty material as diagnostic

The dorsal spine has previously been regarded as too risky a target for puncture (Ottolenghi 1955, Sneppen et al 1974) When our single complication of pneumothorax occurred, it was after aspiration biopsy from the seventh thoracic vertebral body in a patient with severe kyphosis following TB spondylitis

By revision of the primary cytological reports (Table 2) we were able to identify four false positive results in primary tumours all comprising histiocytosis X Two were very cellular specimens and two contained rather scanty but sufficient material to exclude a primary malignant report (Figure 1) The one false negative report could not be changed by revision and the scanty material in this specimen should have indicated repuncture or surgical biopsy However, in most cases it was possible to differentiate between sarcoma and carcinoma (Figure 3) Furthermore in some cases it was possible to classify the carcinomas (Figure 4) By revision of slides from lesions suspected of being metastases malignant cells were found in 35 cases i e 80 per cent This is in accordance with the findings of Stormby & Akerman (1973) In the cases where no tumour cells were found probably two were false negative This finding stresses the importance of repuncture also in cases suspected of having metastases where cytology is inconclusive

CONCLUSION

The most valuable clinical information was gained from the lesions suspected of being metastases This is in contrast to aspiration biopsy of primary tumours where both false positive and negative reports occurred However fine needle aspiration biopsy is a simple method for a primary diagnostic approach especially in metastatic lesions

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Acta orthop scand 47, 144–148, 1976

THE *IN VITRO* ELUTION OF GENTAMICIN SULPHATE FROM METHYLMETHACRYLATE BONE CEMENT

A Comparative Study

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The *in vitro* elution of gentamicin from three brands of bone cement has been studied One was found to have a much longer lasting activity than the other two This activity and the possible deleterious side effects from the use of gentamicin in bone cement as a routine procedure are discussed

Key words bone cement, gentamicin, postoperative infection, total hip replacement

Accepted 18 xi 75

For a number of years the use of methylmethacrylate as a means of fixation of total hip prostheses has been an established part of the procedure

It has however been troubled by an unusually high number of infections, the prevention of which has led to expensive and complicated procedures such as special sterile operating enclosures and special ventilating systems, and even vaccination against staphylococci

It is commonly believed that the infections of total hip replacement (THR) show themselves in two different clinical entities the immediate postoperative infection as seen with other types of surgery and a late infection with an insidious onset after a latent period of up to 1 year or more These infections often necessitate the removal of the prosthesis with considerable loss of function as the result

The late type of infection is believed by some to be derived from bacteria of low virulence, perhaps sometimes anaerobics, from the skin flora mostly, that have been introduced into the wound at the time of surgery (Charnley 1972, Ericson et al 1973, Kamme et al 1974) while others hold the view that a haematogenic infection can occur at a *locus minoris resistentia* (Buchholz & Gartmann 1972)

Hessert & Ruckdeschel (1970) tried to mix methylmethacrylate bone cement (Palacos ®) with tetracycline, a mixture of penicillins, and with gentamicin sulphate Eluting the antibiotic from the polymerized bone cement in 0 8 per cent NaCl they found no trace of tetracycline Of the penicillin mixture, about 5 per cent was found in the solution after 24 hours, but up to 80 per cent of the gentamicin was recovered They used 1 g of

gentamicin in one package of bone cement, concluding that with the use of such a cement a liberation of about 800 mg of gentamicin could be expected. Wahlig & Buchholz (1972) carried out similar experiments using Palacos® as the cement, a phosphate buffer solution as the eluting fluid, and gentamicin as the antibiotic. They found a very long lasting release of gentamicin, lasting for over one year. Buchholz & Engelbrecht (1970) tested the antibiotic effect of penicillin G, erycin heptogluconate, rolitetracycline, and gentamicin sulphate in Palacos® with dextrose agar as the solvent. They found good antibiotic activity with penicillin lasting for over one year. No tetracycline activity was demonstrated. With gentamicin an initially very high concentration was found in the broth. The concentration decreased over 10–12 days to a low value that stayed constant for more than 2 months.

The total amount of gentamicin recovered was about 6 per cent of the initial amount. Wahlig & Buchholz (1972) also examined the serum levels and urine concentrations in rats and dogs after implantation of cement containing gentamicin and measured the same parameters in 20 patients who had THR with gentamicin in the cement. They found very low serum levels for only 1–2 days in both animals and humans. The rats had traceable gentamicin activity in the urine for 22 weeks, whereas the effect in dogs only lasted about 2–3 weeks, the difference presumably being due to characteristics of the species. In two patients in whom the excretion of gentamicin was followed it was no longer traceable in the urine after about 3 weeks, the total excreted amount being about 6 per cent of the amount implanted.

Eicher (Knight, personal communication) mixed the injectable preparation of gentamicin into the cement and by using chromatography, he was able to demonstrate small amounts of the drug in the patients' urine. Wahlig & Hahmeister (1973) tested the liberation of gentamicin from Palacos®. Their results were similar to those of other workers, viz., that small amounts of the antibiotic are set free for very long periods of time. Their experiments lasted for up to 30 months. They implanted the cement in dogs and found concentrations varying from 1 to 54 µg/ml in the wound secretion taken from a cavity in the cement. Sattel & Nabert-Bock (1973) in a comparative study found the release of gentamicin from CMW to last about 4 months whereas Refobacin Palacos® showed antibiotic activity for a much longer period of time. They also examined the contents of gentamicin in the wound drainage after the use of Refobacin-Palacos® in three patients and found concentrations from 20 to 10 µg/ml. They further aspirated the THR's in 30 patients and found antibiotic activity after 264 days with concentrations of 0.2–0.04 µg/ml. *Stohr et al.* (1973) were able to demonstrate gentamicin concentrations in wound secretions of 1–2 µg/ml up to 21 months after insertion of Palacos® with gentamicin. *Gartenmann et al.* (1973) tested the antibiotic effect of Nebacetin (a mixture of neomycin and bacitracin) in combination with Palacos® and CMW Bone Cement® and found a high level of activity after 7 days with the Palacos® mixture. The results with CMW Bone Cement® were significantly poorer. Their clinical results showed no primary infections in 100 cases. A long term follow-up of their material has not yet been done.

MATERIAL AND METHODS

A package of CMW Bone Cement® powder was mixed with 1 g of gentamicin sulphate powder by thorough stirring. The monomer was added and the cement was mixed according to the manufacturer's instructions. The cement was then cast into rods of 10×4×110 mm in a mould. After removal from the mould the samples were machined on one side to the exact thickness of 4 mm. A package of Surgical

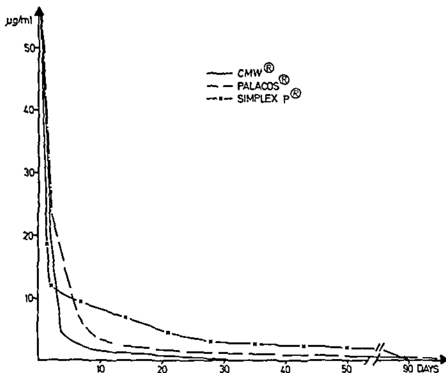


Figure 1
The concentration of gentamicin eluted from three brands of bone cement

Simplex® mixed with 0 5 g of gentamicin sulphate and a package of Refobacin Palacos® were prepared in a similar manner

The samples then underwent mechanical testing to determine the modulus of elasticity and the breaking strength (Results not yet published) The fragments weighing about 1 8 g each were then analyzed as to their antibiotic activity A total of 80 specimens were examined

Determination of antibiotic activity

The rods were placed in tubes surrounded by *human serum The tubes were then placed in a* rolling machine in an incubator at + 35° C The serum was changed every 24 hours

The method used for measuring the concentration of gentamicin has been described previously by Rosdahl et al (1970) First daily and then later weekly samples were taken Results are shown in Figure 1

RESULTS

The release of gentamicin from all the specimens shows a common pattern in that the release is greatest in the first hours after adding the serum and then slowly decreases until the serum is changed, when there again is a sharp rise in output per hour This underlines the simple fact that the release of antibiotic is a diffusion process

In evaluating the results it was considered that although many experiments were carried out each specimen consisted of a portion of the same batch It was therefore felt that although the variations in results from sample to sample were sometimes considerable (up to 2–300 per cent) it would be justifiable to give the results as mean values, the individual variations being due to such factors as uneven mixing of the cement and gentamicin powder or even the presence of a lump of powder on the cement surface This might also occur in the case of clinical use so that the diagrams express the rate of elution from the whole portion of cement (Figure 1) The results show, in accordance with the findings of Wahlig & Hameister (1973), that the gentamicin is initially released in large amounts giving rise to very high concentrations locally In the case of CMW the release diminished to a low level after about 10 days and the activity had ceased after 30 days The Surgical Simplex showed a similar curve although the release was somewhat higher and lasted about 4 months Refobacin-Palacos® also

gave a high initial dosage, but then continued with a slow release for 3 months after which time the experiment was discontinued This level of release corresponded to about 0 5 μg gentamicin per gram of cement per day

DISCUSSION

The present results confirm the findings of others although there are differences in the results of various investigators Sattel & Nabert Bock (1973) found that Palacos® not only had a longer lasting release of gentamicin, but also a higher release This last observation has not been confirmed in the present study, but it seems logical that differences in shape and size of the test bodies, differences in eluting fluids, and in the frequency of fluid change may alter the results In clinical use the release of antibiotic will depend on two factors the surface area of the cement involved and the diffusion gradient, i e the turn over of tissue fluid surrounding the cement This also explains why in the present study the antibiotic activity in CMW had ceased after about 30 days while other investigators (Sattel & Nabert Bock 1973) found a much longer lasting activity since they used cement pieces with irregular surfaces and of twice the size as were used by us

The concentration of antibiotic inside the cement will undoubtedly remain very high and any water absorbed into the acrylic cement and possibly filling the 'vacuoles' in the cement will be saturated with gentamicin

The concept of using a long lasting depot antibiotic in the bone cement rests on the theory of haematogenous infection as the cause of late infections in the THR

The most common type of bacteria in infected THR's is a staphylococcus of some variety or other, but also a number of anaerobics have been found as listed by Buchholz & Gartmann (1972)

Whether this large variety of bacteria, some 20 different kinds, are most likely found in the circulating bloodstream or whether they enter the wound at the time of operation is debatable That haematogenous infection can occur cannot be completely denied, but in the light of present knowledge it is the authors' belief that peroperative infection still seems the most likely route

The claims of Buchholz & Engelbrecht (1970) and of Wahlig & Hameister (1973) that the possibility of toxic and systemic side effects can be ruled out cannot be supported If a THR is implanted using gentamicin in the cement the body will receive and excrete small amounts of gentamicin every day It has yet to be demonstrated that no allergic or long term toxic effects arise from this procedure, especially since the indications for THR tend to include much younger age groups now than some years ago The well known development of allergies in, for instance, chemical and industrial workers to various substances after 10 to 20 years of exposure may be a warning sign Also the risk of developing resistant strains of bacteria must be considered From the point of view of prophylaxis it might therefore be preferable to choose a cement type that does not have the very long lasting effect

It has however been demonstrated (Ericson et al 1973) that through prophylactic usage of systemic antibiotics of proper choice and in adequate dosage the avoidance of infection can be achieved—and this treatment can be discontinued at will It must also be remembered that gentamicin is virtually without effect on anaerobic bacteria However, the excellent results achieved by Buchholz (Buchholz & Gartenmann 1972) show the value of using a bone cement with a long lasting antibiotic effect as a therapeutic measure in trying to salvage an already infected THR

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Acta orthop scand 47 149 157 1976

EVALUATION OF THE PAIN SUPPRESSIVE EFFECT OF DIFFERENT FREQUENCIES OF PERIPHERAL ELECTRICAL STIMULATION IN CHRONIC PAIN CONDITIONS

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The pain suppressive effect of low (2/s) and high (50–100/s) frequency electrical stimulation was studied in 12 patients with severe chronic pain in the back and/or the legs All patients were subjected to a thorough physical examination before and 2–3 weeks after a series of stimulation sessions The stimulation was applied via surface electrodes to areas both segmentally related and segmentally unrelated to the regions of chronic pain Low frequency stimulation induced a partial pain relief in only one patient whereas stimulation with high frequency gave a suppression of pain in seven patients The effect was short lasting in most cases and the pain started to increase usually within 30 min It is concluded that the observed pain *suppression is not* due to psychological factors but to more basic neurophysiological mechanisms Augmentation of the effect after repeated stimulation sessions was not observed neither was there any alteration in the neuro-orthopedic status nor any lasting pain relief in any patient

Key words pain intractable pain analgesia electric stimulation *acupuncture*

Accepted 7 x 75

The treatment of chronic pain conditions still constitutes a serious clinical problem since a causal therapy is *often not* available In many cases the etiology of severe pain is difficult to understand largely because of our sparse knowledge of the basic mechanisms of pain itself Methods involving electrical stimulation of peripheral structures have been *reported to* abolish or diminish the sensation of pain *High frequency* stimulation (50 200/s) applied to painful areas or the corresponding afferent nerves seems to relieve pain *in certain* cases (Wall & Sweet 1967, Meyer & Fields 1972) The contribution of 'unspecific", psychological factors is difficult to evaluate but basic, physiological mechanisms interacting with the perception of pain are also supposed to be involved Thus, stimula*tion of* central nervous structures, such as the dorsal columns, via implanted electrodes has been tried in patients suffering from intractable chronic pain, with success in many cases (Shealy et al 1970, Miles et al 1974)

The interest in the pain suppressive effects of peripheral conditioning stimulation was reinforced by reports made by visitors to The People's Republic of China who claimed that *low frequency* electrical or mechanical stimulation may result in relief of acute pain also (Holmdahl 1973, Kerr 1973, Kaada et al 1974) Electrical stimulation or manipulation of needles in various, often precisely defined, areas or points was said to suppress acute surgical pain totally or partially to the extent of allowing major surgery This type of stimulation is supposed to suppress chronic pain also (Mann et al 1973)

These clinical observations are of interest in relation to studies which have shown that low *frequency (2/s) electrical* conditioning stimulation results in an increase of the pain threshold in teeth (Andersson & Holmgren 1975, Andersson et al 1975 a, b) During stimulation the pain threshold increased gradually and reached its maximum after 15–30 min with an average increase of two to three times the prestimulation control value The pain threshold declined slowly to the control threshold in the post-conditioning period Stimulation of the infraorbital region changed the pain threshold similarly in both the upper and lower jaw and essentially the same results were obtained regardless of whether the electrical stimulation was given via needle or surface electrodes High frequency stimulation (100/s) gave, however, only a transient increase of the pain threshold closely related to the stimulated afferent nerves (Andersson et al 1975 b)

The aim of the present study was to compare the effects of low and high frequency stimulation *in the same individuals*, suffering from long-lasting severe pain, with regard to the following specific questions Can pain relief be obtained? Is the effect segmentally related to the location of the conditioning stimulation? Do repeated sessions give any "cumulative effects"? Do these types of stimulation give any serious adverse reactions in chronically ill patients?

MATERIALS AND METHODS

Subjects

Patients suffering from severe chronic back and/or leg pain were selected from the open ward of the Department of Orthopedic Surgery II at Sahlgren Hospital in Goteborg without any primary regard as to the underlying cause of the pain Twelve patients seven women and five men, 37–73 years old were asked to participate in the study and all accepted The patients were informed individually of the general procedure and were told that the aim was to investigate *if electrical stimulation could influence their* pain but positive suggestions were avoided The case history and actual pre stimulation neuro orthopedic status were thoroughly and independently investigated by two of the authors (G H and O R) They re examined the patients 2–3 weeks after the last stimulation session The underlying disorders varied considerably although no malignant diseases were represented Only a few of the patients showed signs of neurological impairment In nine of the patients one to three myelographies had been performed In nine of the patients one or several operations aimed at relieving the pain disorder had been performed including five explorations because of a suspected lumbar disc protrusion of which only two could be verified The posterior branches of sacral nerves had been resected in six patients All patients had been treated with chemical analgesics and physiotherapy and in several cases nerve blockades by injection of local anesthetics had been tried in particular as tests before nerve resections In spite of these treatments a condition of chronic severe pain persisted which usually had prevented the patients from doing ordinary work for some years

Stimulation procedures

The stimulation sessions were performed at the Department of Physiology and started within one week of the orthopedic examinations The stimulation was performed by two of the authors (S A or F H) or by an assistant under their direct supervision The same type of transcutaneous stimulator was used as in previous studies (Andersson et al 1975 a) i e a square wave stimulator with several transformer isolated outputs giving pulses of 0 2 ms duration The stimulation was applied via surface elec

trodes with a contact area of about 4 cm^2 Repeated stimulation sessions were performed with intervals of one or a few days In the first eight patients the low frequency stimulation (2/s) was presented in the first sessions and high frequency stimulation in the later sessions in the last four patients this order was reversed In the same session either low or high frequency stimulation was performed although different high frequencies (50–100/s) were often tried Each stimulation session lasted for about 1 hour including a short pre stimulation interview The patients were free to use their ordinary analgesics on the days between the sessions but were asked not to take any drugs during the hours prior to the stimulation to avoid an interactive effect between stimulation and drugs

Low frequency stimulation was usually performed with 2–4 pairs of electrodes The stimulation was applied to areas segmentally related as well as unrelated to the region of pain Thus in patients with low back pain radiating into one leg electrodes were applied to the paravertebral lumbar region and to the painful leg but also to the other leg and to the hands The electrodes were placed over large nerves such as the sciatic femoral and peroneal nerves and also in areas overlying large muscle bellies The intensity of the stimulation was increased gradually during the session and adjusted to the maximum level which the patient could accept with regard to the discomfort from the beating sensations and muscle twitches produced

During high frequency stimulation the electrodes were usually placed over the painful areas or over peripheral nerve trunks innervating such areas The intensity was gradually increased to the level just below that tolerated by the patient. The stimulation induced a sensation of intense vibration or paresthesia and fasciculations or tetanic contraction of m scles were fre...

Personality tests

All patients were tested with standardized personality inventories The psychasthenic sthenic (validity) and hysterical nonhysterical (solidity) character variance was evaluated with the MNT scale (Marke & Nyman 1958) and the characters of neuroticism and extra introversion with the Swedish form of Eysenck Personality Inventory (Bederoff Petersson et al 1971)

Evaluation and scoring of effects

Since pain is a subjectively experienced phenomenon the main estimation of the effect of the electrical stimulation had to be made by the patients and reported to the investigators In addition the patient's behavior including body movements and facial expressions were observed and related to the verbal reports No physical examinations were performed in connection with the stimulation sessions The effects of conditioning stimulation summarized in Tables 1 and 2 were scored as follows

Degree of pain relief was noted as *no effect* – weak – fair – good – very good, where "very good" corresponds to a complete abolition of pain *Distribution of effect* was noted as "partial" if the pain was relieved from some parts of the painful area and as "general" if the pain was relieved in the whole region *Post stimulation duration* indicates the period between the discontinuation of the stimulation and the start of pain increase after a pain reduction *Reproducibility* indicates similarity in effects at repeated sessions *Adverse effects* notes all disturbances reported by the patient as due to the stimulation

These aspects of the effects and the results of the physical re examination were summarized as the *Evaluated effect* which was ranged as no effect – weak – fair – good – very good "Weak" indicates the report of minor changes such as "pleasant warmth" although the effect on the pain as such was very uncertain "Very good" indicates a total pain abolition of a general distribution and with a post stimulation duration of at least 1 hour "Good" indicates a substantial pain relief although either a subtotal abolition a partial distribution of the effect or a short post stimulation duration did not justify the score "very good" "Fair" denotes a significant although less strong and often variable effect

RESULTS

Effects of low frequency (2/s) stimulation

The results obtained with conditioning stimulation of 2/s are summarized in Table 1 All patients were stimulated at several, usually 3–12, sessions The pain relief obtained using this frequency was reported to be weak or non-existent in all cases except one During the stimulation some patients experienced "a pleasant sensation" or "a pleasant distraction"

Table 1. Effect of 2 Hz condition

Subj no	Number of sessions	Degree of pain relief	Distribution of effect	Post stimulation duration
1	23	weak	partial	~ ½ day
2	12	weak	partial	~ ½ hour
3	11	weak	partial	~ ¼–½ hour
4	11	weak	probably general	1–2 hours
5	5	weak	probably general	~ ¼–½ hour
6	3	none	—	—
7	6	weak	probably general	¼ hour
8	5	none	—	—
9	4	weak	partial	—
10	1	none	—	—
11	2	good	partial	~ 2 hours
12	3	weak	general	0

either at the electrode sites or more generally. Although the patients often interpreted this type of sensation as a "weak" pain relief when it first was experienced, it became apparent after repeated stimulation sessions, when the patients looked more critically away from the distraction produced by stimulation as such, that the underlying pain sensation was unchanged. No tendency to a cumulative effect appeared at repeated stimulation sessions. No serious adverse effects appeared during the stimulation sessions or were reported to have appeared in the intersessional days.

An important adverse effect, which to some extent restricted the applicability of the method in these patients, however, was the tendency for increased local tenderness when the stimulation was applied to the painful areas. During stimulation the intensity was increased to the level which the subject could just tolerate and efforts were made to increase the intensity successively. It was only possible in exceptional cases to reach intensities corresponding to those required to induce a pain threshold increase in healthy subjects (Andersson et al. 1975b, Holmgren 1975) when the stimulation

Table 2. Effect of 50–100 Hz condition

Subj no	Number of sessions	Degree of pain relief	Distribution of effect	Post stimulation duration
1	3	good	partial	0–few min
2	7	good – very good	general	few min
3	3	none	—	—
4	5	weak	probably general	0
5	4	fair	partial – general	few min – ½ hour
6	3	none	—	—
7	4	good	partial – general	few min – 1 hour
8	3	weak	probably partial	0
9	8	very good	partial	few min
10	7	very good	general	2–8 hours
11	4	good	partial	few min – ½ hour
12	6	weak	general	0

ulation on severe chronic pain

producibility	Cumulative tendency	Adverse effects	Evaluated effect
yes	none	Followed by tiredness	weak
yes	none	Followed by tiredness dry mouth	weak
yes	none	Followed by slight myalgia	weak
yes	none	Followed by tiredness and slight incoordination in hands	weak
yes	none	Sometimes followed by increased pain	weak
yes	none	Local tenderness	none
yes	none	Often followed by pain increase	weak
yes	none	None	none
weak	none	None	weak
?	?	Followed by beating sensation in legs	none ?
yes	none	Occasional muscle spasms	good
yes	none	None	weak

was applied in or close to regions of pain It was however, often possible to stimulate with higher intensities in segmentally unrelated areas (for example bilaterally in the hands in cases of low back pain) No additional pain blocking effect could be obtained by such nonsegmental stimulation Only in one case (No 11) was a more substantial pain relief found by the 2/s stimulation In this patient the experience of a dull intense pain in the legs and the intense hyperesthesia around skin scars became markedly depressed a few minutes after the start of the conditioning stimulation and during a post stimulation period of about 2 hours These effects were well reproducible even during repeated stimulations performed by the patient himself at home

In summary In this series of patients with severe chronic pain 2/s conditioning stimulation induced obvious effects on the pain in only one out of 12 subjects

Effects of high frequency (50–100/s) stimulation

The effect of high frequency stimulation is summarized in Table 2 All pa

ulation on severe chronic pain

eproducibility	Cumulative tendency	Adverse effects	Evaluated effect
yes	none	None	good
yes	none	Followed by weak paresthesia.	good
yes	none	Followed by slight local back tenderness	none
yes	none	Unpleasant vibratory sensation	weak
variable	none	100 Hz "tearing	fair
yes	none	Sometimes followed by increased pain	none
yes	none	Occasional radiating pain	good
yes	none	None	weak
yes	none	None	good
yes	none	Occasional muscle spasms	very good
yes	none	Occasionally pain switched to opposite leg	good
yes	none	None	weak

Table 1 Effect of 2

Subj no	Number of sessions	Degree of pain relief	Distribution of effect	Post u
1	23	weak	partial	~
2	12	weak	partial	~
3	11	weak	partial	~ 1/[illegible]
4	11	weak	probably general	1–2
5	5	weal	probably general	~ 1/4
6	3	none	—	
7	6	weak	probably general	1/4
8	5	none	—	
9	4	weak	partial	
10	1	none	—	
11	2	good	partial	~ 2
12	3	weak	general	l

either at the electrode sites or more generally Although the patients often interpreted this type of sensation as a "weak" pain relief when it first was experienced, it became apparent after repeated stimulation sessions, when the patients looked more critically away from the distraction produced by stimulation as such, that the underlying pain sensation was unchanged No tendency to a cumulative effect appeared at repeated stimulation sessions No serious adverse effects appeared during the stimulation sessions or were reported to have appeared in the intersessional days

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Table 2 Effect of 50–100 Hz c

Subj no	Number of sessions	Degree of pain relief	Distribution of effect	Post stimu durati
1	3	good	partial	0–few
2	7	good – very good	general	few
3	3	none	—	—
4	5	weak	probably general	0
5	4	fair	partial – general	few min – '
6	3	none	—	—
7	4	good	partial – general	few min – 1
8	3	weak	probably partial	0
9	8	very good	partial	few m
10	7	very good	general	2–8 hou
11	4	good	partial	few min – ½
12	6	weak	general	0

ulation on severe chronic pain

...producibility	Cumulative tendency	Adverse effects	Evaluated effect
yes	none	Followed by tiredness	weak
yes	none	Followed by tiredness dry mouth	weak
yes	none	Followed by slight myalgia	weak
yes	none	Followed by tiredness and slight incoordination in hands	weak
yes	none	Sometimes followed by increased pain	weak
yes	none	Local tenderness	none
yes	none	Often followed by pain increase	weak
yes	none	None	none
weak	none	None	weak
?	?	Followed by beating sensation in legs	none ?
yes	none	Occasional muscle spasms	good
yes	none	None	weak

was applied in or close to regions of pain It was however often possible to stimulate with higher intensities in segmentally unrelated areas (for example bilaterally in the hands in cases of low back pain) No additional pain blocking effect could be obtained by such non segmental stimulation Only in one case (No 11) was a more substantial pain relief found by the 2/s stimulation In this patient the experience of a dull intense pain in the legs and the intense hyperesthesia around skin scars became markedly depressed a few minutes after the start of the conditioning stimulation and during a post stimulation period of about 2 hours These effects were well reproducible even during repeated stimulations performed by the patient himself at home

In summary In this series of patients with severe chronic pain 2/s conditioning stimulation induced obvious effects *on* the pain in only one out of 12 subjects

Effects of high frequency (50–100/s) stimulation

The effect of high frequency stimulation is summarized in Table 2 All pa

mulation on severe chronic pain

Reproducibility	Cumulative tendency	Adverse effects	Evaluated effect
yes	none	None	good
yes	none	Followed by weak paresthesia	good
yes	none	Followed by slight local back tenderness	none
yes	none	Unpleasant vibratory sensation	weak
variable	none	100 Hz "tearing	fair
yes	none	Sometimes followed by increased pain	none
yes	none	Occasional radiating pain	good
yes	none	None	weak
yes	none	None	good
yes	none	Occasional muscle spasms	very good
yes	none	Occasionally pain switched to opposite leg	good
yes	none	None	weak

tients were stimulated at several (3–8) sessions, and the conditioning stimulation was often repeated several times during each session sometimes with different frequencies within the high frequency range The effect of high frequency stimulation on the pain was quite different as compared to that of a frequency of 2/s A marked pain relief was achieved in seven of the patients within one or a few minutes when stimulation was applied to the painful areas or to areas overlying nerves innervating the regions of pain Three patients experienced, at repeated sessions, a total suppression of a very intense pain Within minutes after the onset of the stimulation, the perception of pain was abolished and the patients could lie quietly with a relaxed facial expression, only experiencing the buzzing sensation of the stimulation In four patients a "fair" to "good" pain relief was achieved, i e depression of the pain was judged as significant although not total The *distribution of the pain relief* was *closely* related to the region innervated by the stimulated nerves In patients with a wide distribution of pain it was often difficult to suppress the pain in the entire painful area In five patients the pain was not influenced by the high frequency conditioning stimulation, although the stimulation procedure was the same as in the responsive patients The post-stimulation duration of the effect varied between individuals but the effect persisted after stimulation in all responsive subjects In three patients the after-effect varied between a few minutes and 30 to 60 min and in one subject it lasted several hours The reproducibility of the pain-relieving effects was good Any cumulative tendencies such as increasing pain suppression or more long lasting effects were not observed Most stimulations were performed with 50/s or 100/s These frequencies essentially induced the same subjective sensations and pain relief In some patients and 25/s were also used The pain given by these frequencies was re[illegible] to be less than with the highe[illegible] quencies

No serious adverse effects we[illegible] ported Occasionally, increased, lasting, radiating pain was evoked [illegible] stimulation Some patients with [illegible] nounced pre-stimulation tenderne[illegible] muscle rigidity reported a slight[illegible] creased tenderness and rigidity d[illegible] the post-stimulation periods, alt[illegible] pain relief was reported during the [illegible]ulation In no case did such sym[illegible] last until the next day

In summary High frequency [illegible]mental stimulation induced pain [illegible] in seven out of 12 patients with s[illegible] chronic pain

Relation between pain relieving effe[illegible] and psychological factors

No obvious relation was found bet[illegible] the pain relief during the high frequ[illegible] conditioning stimulation and any o[illegible] personality traits tested The small n[illegible]ber of patients does not allow a statis[illegible] evaluation It should, however, be [illegible]tioned that a subgroup of four pati[illegible] characterized by subvalidity, corresp[illegible]ing to a psychasthenic personality [illegible] combination with a relatively high [illegible]gree of suggestibility (subsolidity) [illegible] not differ with regard to pain relief f[illegible] the test group as an entity

Orthopedic re-examinations

At the interview and physical exami[illegible]tion 2–3 weeks after the last stimul[illegible] session, the patients gave essentially [illegible] same report on the subjective sensat[illegible] and the effect on the perception of p[illegible] as reported during the stimulation s[illegible]sions In no case was there any last[illegible] improvement of the basic pain conditi[illegible] neither was any alteration of the neu[illegible] orthopedic status observed

Table 3 *Effect of electrical conditioning stimulation on severe, chronic pain*

Subject			Stim freq, 2 Hz				Stim freq, 50–100 Hz			
No	Sex	Age (years)	non exist or weak	fair	good	very good	non exist or weak	fair	good	very good
1	♀	63	×						×	
2	♀	45	×						×	
3	♂	45	×				×			
4	♀	46	×				×			
5	♀	51	×					×		
6	♀	39	×				×			
7	♂	48	×						×	
8	♀	53	×				×			
9	♀	37	×						×	
10	♂	53	×							×
11	♂	59			×				×	
12	♂	73	×				×			

DISCUSSION

The effects of stimulation with low and high frequencies are summarized in Table 3 The reports of "a feeling of warmth' or "pleasant sensation' should be considered as a distraction which also became evident to the patients after repeated sessions Such distractory phenomena are indicated as "*no effect*" in Table 3 No serious adverse effects of either low or high frequency stimulation were reported, neither did the physical re examination disclose any impairment or improvement of the neuro-orthopedic status Some patients complained of slight disturbances such as tiredness myalgia or increased tenderness, but some of these effects may have been due to traveling to the laboratory rather than to the stimulation itself

The results show that the possibility of suppressing severe chronic pain is markedly related to the frequency of the conditioning stimulation In the present group of 12 patients only one experienced real pain relief during 2/s stimulation compared to a suppression of pain in seven patients when the conditioning was performed with high frequencies These effects seem to be in contradiction to the effects on the pain threshold observed in healthy volunteers (Andersson & Holmgren 1975, Andersson et al 1975 a, b) who showed a marked increase of the pain threshold in the teeth by 2/s conditioning stimulation of the cheeks but only transient threshold effects during stimulation with 100/s It is, however, not possible to make a direct comparison The most important factor to consider is the intensity of the conditioning stimulation The patients with severe pain were not able to tolerate strong stimulation since the beating sensation and the muscle twitches elicited by low frequency stimulation produced considerable discomfort or even pain and it was not possible to reach the high intensity of the conditioning stimulation required to induce the increase of the pain threshold (Andersson et al 1975 b, Holmgren 1975) Both Chinese and Western clinical reports emphasize the importance of a sufficient intensity of the conditioning stimulation (Holmdahl 1973, Peking Acupuncture Anaesthesia Co-ordinating Group 1973), and in some Chinese reports it is claimed that the efficiency in suppression of pain is dependent on the patient's ability to tolerate the conditioning as such (Department of Anesthesiolo-

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11	♂	59			×				×	
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No serious adverse effects were reported Occasionally, increased, short lasting, radiating pain was evoked by the stimulation Some patients with pronounced pre-stimulation tenderness or muscle rigidity reported a slightly increased tenderness and rigidity during the post-stimulation periods, although pain relief was reported during the stimulation In no case did such symptoms last until the next day

In summary High frequency segmental stimulation induced pain relief in seven out of 12 patients with severe chronic pain

Relation between pain relieving effects and psychological factors

No obvious relation was found between the pain relief during the high frequency conditioning stimulation and any of the personality traits tested The small number of patients does not allow a statistical evaluation It should, however, be mentioned that a subgroup of four patients characterized by subvalidity, corresponding to a psychasthenic personality, in combination with a relatively high degree of suggestibility (subsolidity) did not differ with regard to pain relief from the test group as an entity

Orthopedic re-examinations

At the interview and physical examination 2 3 weeks after the last stimulation session, the patients gave essentially the same report on the subjective sensation and the effect on the perception of pain as reported during the stimulation sessions In no case was there any lasting improvement of the basic pain condition, neither was any alteration of the neuro orthopedic status observed

ACKNOWLEDGMENTS

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gy Peking 1973) Thus it can be assumed that the intensity of conditioning stimulation required to give a pain suppression from 2/s stimulation was not reached This conclusion necessitates further investigations in patients suffering from pain conditions which in themselves do not prevent sufficient intensity being used It is also important to note that chronic pain can be considered as neurophysiologically and psychologically different from experimental pain and it is difficult to predict the effect on clinical pathological pain from pain threshold measurements only (Houde 1966 Andersson & Holmgren 1975)

From a clinical point of view conditioning stimulation with 2/s had very little to offer as a complement to other pain relieving methods since only one patient out of 12 obtained a good pain relief after the stimulation The high frequency conditioning stimulation however gave pain relief in seven of the patients This observation is in agreement with other reports on transcutaneous high frequency stimulation (Wall & Sweet 1967 Shealy & Maurer 1974 Augustinsson et al 1974) The long term effect of transcutaneous stimulation is not yet known but experiences from dorsal column stimulation via implanted electrodes indicate a decreasing effect after months or years of use (Nashold & Friedman 1972) Since pain relief is obtained only in some of the patients and since the post stimulation effect is short and possibly decreases during long term use it is important to elucidate underlying neurophysiological mechanisms in order to improve the method

With regard to the present effects on pain conditions psychological factors have to be considered All the patients had previously been treated with various methods aimed at reducing their pain including surgery chemical analgesics and injections of local anesthetics in combination with strong suggestive influences without any lasting effect on the pain Furthermore patients 1–8 were initially conditioned with 2/s stimulation without any significant effect on the pain It should be noted that the patients participated in the investigation with a great expectation of being relieved from pain although positive suggestions regarding pain suppression were avoided During the period of successive stimulations at 2/s some degree of disappointment developed regarding the stimulation procedure Several of these patients experienced a substantial pain relief when they later were conditioned by high frequency This effect can hardly be due to suggestive factors since they would already have been disclosed at the initial series of stimulations We therefore conclude that the pain suppression is not due to a mere psychological distraction or suggestion but implies a basic neurophysiological mechanism

Empirical evidence indicates that activity in non pain afferents blocks the sensation of pain Melzack & Wall (1965) proposed a gate control theory according to which activity in low threshold large diameter afferents closes a "gate in the pain pathway Several of the specific features in this model have been severely criticized (Franz & Iggo 1968 Zimmermann 1968 Vyklický et al 1969 Schmidt 1972 Whitehorn & Burgess 1973) An alternative theory explaining the segmental and to a certain extent non segmental effects on the pain threshold and on the pain obtained by high and low frequency conditioning stimulation has been proposed This theory takes into account the segmental organization of the central connections from the afferents which elicit the flexion reflex as well as the supraspinal control of these connections An extensive discussion of these mechanisms is given elsewhere (Andersson & Holmgren 1975)

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Acta orthop scand 47, 158-166, 1976

POROUS CERAMICS AS A BONE SUBSTITUTE IN THE MEDIAL CONDYLE OF THE TIBIA

An Experimental Study in Sheep

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A new porous ceramic material was tested for possible use as a bone substitute in regions exposed mainly to compressive forces The porous ceramics were implanted into the medial condyle of the tibia of four sheep and left in position for 3 months The operated tibia was then removed and sections were made of the implants The sections were studied by transmitted light microscopy, microradiography and scanning electron microscopy There was no apparent loss of function of the operated leg and the implants were found to be bound to the adjacent bone by ingrowth of bony tissue, in some regions to a depth of 2 3 mm It is concluded that the properties of the porous ceramic implants justify a clinical trial provided that the results of long term animal experiments are equally satisfactory

Key words bone substitute, porous ceramics, tibial condyle fracture

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Bone substitutes are frequently required in orthopaedic surgery, both for the correction of acute traumatic lesions with bone loss or destruction, and as a substitute for chronically destroyed parts

Various types of materials have been used, the most notable being metal alloys, devitalized animal bone (Kieler-Knochen-Span) and autogenous cancellous bone None of these materials are ideal, however, either they are rigid, but fail to adhere permanently to the adjacent bone, or they are fragile and easily crushed The search for new and more suitable bone substitutes therefore continues

The possibility of employing ceramics has received increasing attention in recent years These materials have a high degree of bio-compatibility, and it has been shown that small porous ceramic implants become anchored to the adjacent bone by invasion of bony tissue (Hulbert et al 1971) The mechanical properties of the ceramics, especially their tendency to brittle fracture, limit their applicability as bone substitutes But the compressive strength is high and as the physical properties to a certain extent may be modified by varying the chemical composition, structure and density, they may be useful as implants in regions which are mainly exposed to compressive forces

The purpose of the present study was

to determine whether porous ceramic implants were suitable as bone substitutes in weightbearing parts, exposed only to minor tensile and shearing forces. We have studied the fate of porous ceramics implanted into the medial condyle of the tibia of sheep.

MATERIAL AND METHODS

The implants were made from porous ceramics produced as described by Lyng et al. (1973). The material consists of 99 per cent (by weight) of Al_2O_3 and 1 per cent CaO, MgO and SiO. The firing temperature was 1700° C and the soaking time 4 hours. Pore size was 100–1000 μ and the compressive strength of cylinders with diameter 10 mm and height 10 mm measured by standard methods, was 27 MN/m^2 (varying from 20–34 in 10 samples). In comparison it may be mentioned that the mean compressive strength of Kieler Knochen Span was found to be 5 MN/m^2 (varying from 2 to 10 in five samples).

Reports in the literature, Burke et al. (1971), Frakes et al. (1974) and Schnittgrund et al. (1973) indicate that the strength of alumina may deteriorate due to stress corrosion both in vivo and in vitro. However, according to Schnittgrund et al. the changes are less severe in vivo than in the in vitro tests.

Compact samples of the above mentioned materials were therefore subjected to a dynamic fatigue test, and the tensile strength of the samples before and after cycling measured. The samples submerged in Ringer solution at 37° C, were subjected to 10^7 cycles with a load of 20–1600 N (The dimensions of the samples were 10×10×60 mm, support distance in the test machine 50 mm).

The tensile strength of these specimens was reduced approximately 40 per cent after cycling from 305 to 180 MN/m^2).

The height of the implants used in the present experiments was 10 mm; their shape can be seen in Figure 1.

Animals

The animals used were four female sheep weighing from 40 to 60 kg and aged from 5 to 8 years. Epiphyseal fusion of the tibia had occurred in all animals prior to the operation.

Surgical procedure

The operation was carried out under nembutal anaesthesia (Nembutal Veterinary ® Abbott 0.5 mg/kg body weight intravenously in one initial dose with supplementary doses of 1–2 mg/kg

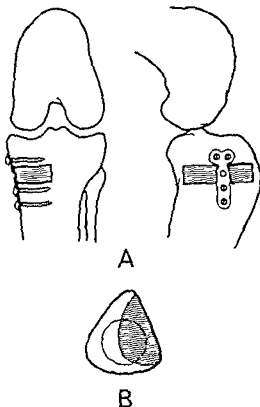


Figure 1. A. Schematic illustration of the experimental model, frontal and medial view. B. Cross section showing the position of the implant (hatched) relative to the supporting surface of the tibia.

when required) under strictly sterile conditions. The proximal medial part of the left tibia was approached through an anteriorly curved incision running from the posterior part of the joint to the tibial tuberosity. The antero medial surface of the tibial condyle was freed from muscular attachments by subperiostal elevation, and a 10 mm high bone segment was removed by means of a double bladed electric saw and an osteotome. The resection was made parallel to the joint surface at a distance of approximately 1 cm. It extended from the tibial tuberosity to the medial crest of the tibia and produced a defect which encompassed the major part of the medial condylar area (Figure 1 A).

The defect needed minor extensions before the preformed porous implant would fit in snugly. The medullary cavity of the tibia extended to the lower resection level; the lateral part of the implant was therefore supported mainly by cortical bone, while the rest of the implant was in contact with trabecular bone (Figure 1 B).

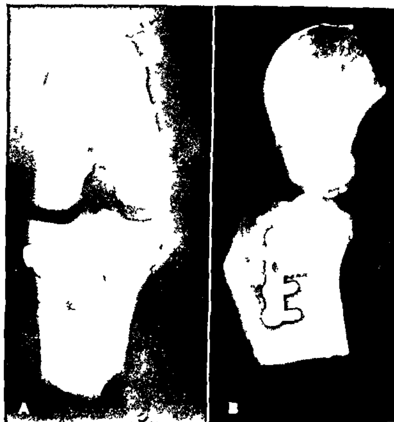


Figure 2 Radiographs of an implant 3 months postoperatively A Frontal view B Lateral view There is no sign of bone resorption around the implant and no collapse of the overlying joint surface

The implant was kept in position by a small A O fingerplate placed across the bony defect as shown in Figure 1 A The compressive load on the implant was measured by inserting a snugly fitting pressure transducer into a corresponding defect in a sheep cadaver tibia it was found to be roughly one fifth of the applied load on the tibial plateau

Postoperative regimen

No restrictions were put on the operated animals they started weightbearing as soon as they recovered from the anaesthesia The animals were transferred to their home farm after 7 days and allowed to roam the range with the rest of the flock until they were sacrificed 3 months later

Investigative procedure

Immediately after sacrifice the operated knee joint and proximal tibia was removed and inspected The soft tissue was cut away and the specimen fixed in 4 per cent formaldehyde for 24 hours The specimen was then X rayed dehydrated by successive soaking for 24 hours in 70 80 90 and 100 per cent alcohol and embedded in methylmethacrylate

After complete polymerization and cooling sections 300 μ thick were cut at 700 μ intervals with a diamond saw The sections were cut vertically through the implant in three specimens and horizontally (parallel to the joint surface) in the fourth

Contact micro radiographs were taken as described by Jowsey et al (1965) the sections were then fixed with epoxy in well slides ground down to a thickness of 40 50 μ and stained with Paragon 1301 (Paragon PS 1301 Paragon C C Co Inc Bronx N Y USA)

The slides were examined by light microscopy Some unmounted and unstained sections were examined with scanning electron microscopy (SEM) to determine the distribution and semi quantitative amounts of Al P and Ca

RESULTS

Function and macroscopic appearance

All the four animals appeared to recover normal function of the operated limb within a week and no limping or other malfunction was observed on the range

When inspected after sacrifice the operated parts exhibited no sign of infection or local reaction to the implants

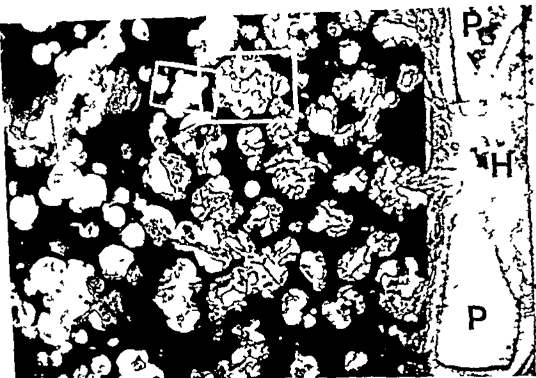


Figure 3. Photomicrograph of a section cut horizontally through an implant (Paragon × 18). The picture demonstrates that the pores of the peripheral part of the implant (near the plate P) contain bony tissue (details in Figure 4) while the pores of the more central region (to the left) are filled with fibrous tissue (details in Figure 5). (The section has been cut at the level of the empty hole (H) in the plate—see Figure 1 A)

and there were no signs of loosening of the implants or fracture of the condylar areas.

Radiological examination

There were no signs of collapse of the implants or of the overlying joint surface, nor were there any osteolytic changes around the implants. To the contrary, there appeared to be continuity between the implants and the adjacent bone (Figure 2).

Histological examination

Some bone tissue was found in the peripheral parts of all implants, but the extent of bony invasion varied greatly. In some regions the bony tissue only extended into the surface irregularities of the implant, in others it infiltrated the superficial layer of pores, and in some regions bony tissue was found to a depth of 2–3 mm. As a rule bony tissue was found in all regions of the implant which were in contact with bone. The pores which did not contain bone were filled with connective tissue (Figures 3, 4 and 5).

The bony tissue seemed to be in intimate contact with the ceramics in some parts of the pores (Figure 4), in others a brim of unossified tissue was interposed. There were no histological changes indicating local tissue reaction to the implants.

The microscopy further showed that there was osteoid tissue in some pores

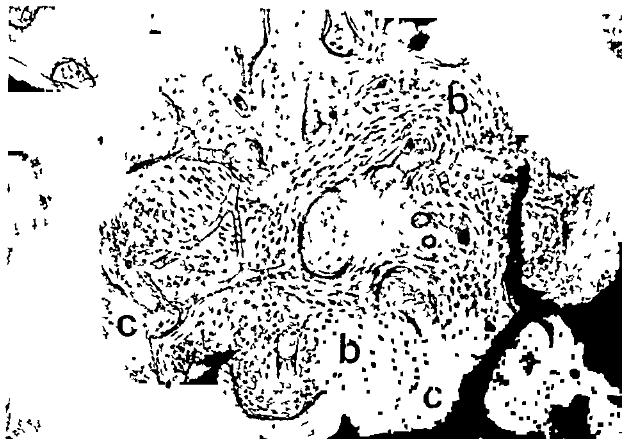


Figure 4 Detail of the larger demarcated area in Figure 3 (× 110) The picture shows a po almost completely filled with bone (b) In some regions fibrous connective tissue (c) is interpos between the bony tissue and the ceramics

with evidence of osteoblastic activity (Figure 6) In some of the widest pores the bony tissue appeared to be arranged in Haversian systems as judged by ordinary light microscopy

Microradiography

The microradiographic findings corresponded closely to those of light microscopy bony tissue was found at varying depths of the implants in different regions (compare Figure 7 with Figures 3 5)

Scanning electron microscopy (SEM)

The SEM pictures indicated heavy concentrations of Ca and P in the regions which histologically contained new bone Correspondingly negative images were obtained when the SEM was carried out to visualize Al A few areas were blan on both types of SEM these containe vessels connective and osteoid tissue

The quantities of Ca and P in the ne bone inside the implants appeared to b nearly as large as those in the adjacen cancellous bone (Figure 8)

DISCUSSION

The success of implants as substitute for bone depends on several factors th implant must be biologically compatibl with the host tissue it must have a surface or construction which allows i to be firmly anchored to the adjacen bone and it must be strong enough t meet the physical demands in the implant situation

The porous ceramic material used in the present study appears to fulfil the



Figure 5 Detail of the smaller demarcated area in Figure 3 (× 180) The picture shows a pore filled with connective tissue

first requirement both the present study and two previous studies (Lyng et al 1973 Pedersen et al 1974) show that it is biologically inert within the time intervals of the observations

In vitro fatigue tests showed a deterioration of strength for compact samples a deterioration which may be still more serious for porous samples due to the much larger surface areas open to corrosive attacks The effect of such effects *in vivo* for the actual samples is at present not known

One also has to take the brittle nature of ceramics into account The usual engineering principle of dimensioning the part according to the tensile stresses in the area has to be replaced by a statistical statement about the possibility of sustaining the actual tensile stresses for a defined period Furthermore according to the weakest link theory it is not possible to obtain higher strength of a ceramic construction detail by using larger dimensions due to the possibility of critical stress concentrations at for example microcracks leading to fracture

In order to avoid these problems we chose an implant site where the ceramics were mainly subjected to compressive forces which are not thought to be critical

Alumina has previously been used in the construction of total hip prostheses as described for example by Heimke et al (1974) Their results indicate that brittle fracture is not too critical a factor for such a use However, the problems mentioned must be reviewed before clinical testing of ceramic materials

The difficulty of obtaining firm fixation of the implant to the adjacent bone depends not only on the surface and construction of the implant but also on the



Figure 6 Photomicrograph demonstrating a row of osteoblasts (indicated by arrows) (Paragon × 180)

possibility of relative movements between bone and implant In cases where such movements are possible, the tissue seems to remain fibrous, ossification does not occur (Lyng et al 1973) Compressive forces on the other hand give close contact between implant and bone and appear to promote the formation of new bone in the border area

In the present study the implants were exposed mainly to compressive forces and all the investigation methods used show that ossification had occurred in the implants, in some regions to a depth of 2–3 mm The trabeculae of the adjacent bone were directly continuous with those of the new bone in the pores of the implant, and microscopy gave evidence of osteogenic activity, indicating that ossification was still progressing Further studies are required to determine how long this process continues, and at what depth the bony invasion finally stops

The medial condyle of the tibia was chosen as the implantation site in the present series, as this is one of the most common sites for implantation of bone substitutes in clinical practice Indeed implantation of Kieler-Knochen-Span or autogenous bone transplants is almost routinely required in the operative correction of compression fractures of the knee joint Porous ceramics appear to present a favourable alternative to Kieler Knochen-Span, and possibly also to autogenous bone grafts The ceramics are more resistant to compression than dry Kieler-Knochen-Span, and the latter material is even weaker when moistened, as it usually is during implantation Moreover, the ceramics probably retain adequate compressive strength, while that of Kieler-Knochen-Span and autogenous

Figure 7 Microradiograph of the section from which the slide shown in Figure 3 was prepared (× 18) Most of the pores of the peripheral part of the implant (near the plate P) are filled with bony tissue

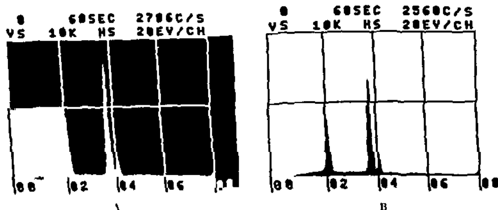


Figure 8 Energy dispersive X ray analysis demonstrating the relative quantities of P (left) and Ca (right) in the bone outside an implant (A) and within a pore (B) The content of Ca and P of the bony tissue within the pore is only slightly lower than in the bone outside the implant

Bone transplants may be gradually lost due to resorption On the other hand the ceramics remain imbedded in bone as a foreign body and it may therefore represent a possible focus of infection This risk is shared by all foreign material implants however, and the properties of the porous ceramic implants are such that



Figure 6 Photomicrograph demonstrating a row of osteoblasts (indicated by arrows) (Paragon × 180)

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Acta orth p scand 47 167 169 1976

STRESS FRACTURES

SOREN PILGAARD, JENS O POULSEN & JORGEN HESLOP CHRISTENSEN

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An unusual case of bilateral stress fracture in the upper third of the tibia which was not diagnosed until 2 months after the onset of symptoms is presented The mechanism symptoms and early X ray findings are discussed and the literature is reviewed

Key words fatique fractures stress

Accepted 11 x 75

Stress fractures in the metatarsal bones are well documented and as a rule easy to diagnose Judging from the literature the incidence of stress fractures in children is higher in the proximal part of the tibia than in the metatarsal bones In children these fractures can give diag nostic problems as the X ray finding may resemble osteosarcoma or osteomyelitis As there are few reports regarding bilater al symmetrical stress fractures of the proximal part of the tibia it was con sidered worthwhile to report such an oc currence in a 14 year old girl

CASE HISTORY

A 14 year old school girl was seen in the out patient clinic at the Orthopaedic Hospital in Aarhus in September 1972 Four months earlier she had noticed pain below both knees after she had been hill climbing on a school field trip

Two months after the onset of the symptoms X rays had been taken at the local hospital The pictures showed transverse fractures 10 cm below both proximal epiphyseal plates There was a marked periosteal reaction on both sides (Figure 1)

When we saw her 4 months after the field trip she was without complaints X rays showed the fractures to be healing (Figure 2) Clinically there was no tenderness and on both sides there was a slight thickening medially above the site of the fracture Blood calcium phosphorus and alkaline phosphatase values were within the normal ranges No treatment has been given except that she has not been allowed to take part in gymnastic or sporting activities

Two years after the start of the symptoms she was completely without complaints The X ray pictures showed nothing abnormal

DISCUSSION

Repeated forceful muscle pull or weight strain can give rise to stress fractures in normal bones (Devas & Sweetman 1956 Burrows 1956, Devas 1958) Bone tissue is sensitive to changes in stress. Im mobilization of bones and non physiolog ical strain on normal bone tissue can result in bone resorption (Blickenstaff & Morris 1966)

Johnson et al (1963) studied 30 stress fractures in the upper part of the tibia by performing biopsies During the first week no decalcification was seen, but active osteoplastic resorption of the tibial cortex was noticed During the second week periosteal callus formation was pre-

we feel that a clinical trial is warranted, providing the results are equally satisfactory after a supplementary study with a prolonged observation period

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Johnson et al (1963) studied 30 stress fractures in the upper part of the tibia by performing biopsies During the first week no decalcification was seen, but *active* osteoplastic resorption of the tibial cortex was noticed During the second week periosteal callus formation was pre





Figure 1

sent If the stress-provoking activity was discontinued, no fracture developed If the force continued, one third of the bones developed fractures Resorption was completed by the end of 3 weeks, callus formation reached a maximum in about 6 weeks In the case reported here there had been no non-physiological strain on the tibial bones when the symptoms started

In children the localization of stress fractures in the upper one third of the tibial shaft is characteristic (Devas 1963) In adults stress fractures are most commonly localized in the lower one third of the tibial shaft (Singer et al 1954) In ballet dancers the fractures are often seen in the middle of the tibia (Burrows 1956), whereas in professional runners oblique stress fractures are seen (Devas 1958)

The common age for the fractures to occur is at about 20, but they are seen as early as 5 years of age (Devas 1963) The fractures can be multiple, symmetrical localization as reported here is not uncommon





Figure 2

The symptoms often start slowly with pain increasing over a period, often after physical activity Clinically there is tenderness below and over the fracture line, caused by the periosteal loosening The initial bone resorption is seen on X-ray The early X-ray changes with abundant periosteal callus formation may give a picture resembling an osteogenic sarcoma, but changes in the X ray picture after a few weeks confirm the diagnosis of stress fracture Actual fracture lines can be seen The treatment is conservative with diminished weightbearing until the patient is free from pain

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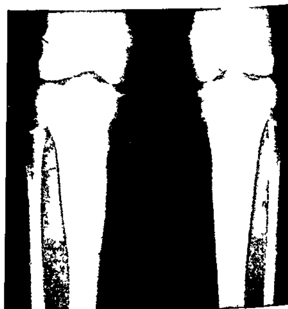




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In children the localization of stress

Table 3 Classification of 34 bone tumours

Benign		Malignant	
Histiocytosis X	9	Ewing's sarcoma	9
Angioma simplex	1	Reticulum cell sarcoma	2
Aneurysmal bone cyst	2	Endothelial sarcoma	1
Osteochondroma	1	Chondrosarcoma	2
Osteoclastoma	2	Osteosarcoma	2
Osteoblastoma	1	Teratoid tumour	1
Osteoid osteoma	1		
Total	17		17

All except five cases of histiocytosis X in the spine were verified by biopsy One case of chondro sarcoma had a negative biopsy but the patient died a few months later from the tumour

Table 4 Primary complaints

	Benign tumours	Malignant tumours
Fatigue		2
Lump	3	3
Local pain	15	12
Radiating pain	3	11
Paraesthesia	1	4
Weakness		4
Disturbance of motility *	3	6
Fever		2

* Disturbance of motility includes paraplegia in two cases

the histological classification of the various tumours ESR and the level of alkaline phos phatase were noted Finally all X rays were reviewed in order to evaluate typical or patho gnomonic findings

RESULTS

The age and sex distributions can be seen in Table 1 The site and histological types of the different tumours are indicated in Tables 2 and 3 The most significant primary complaints can be found in Table 4 The mean duration of primary complaints, survival rate and follow up are shown in Table 5 The most frequent laboratory features are shown in Table 6 Figures 1–11 show some X-rays of various benign and malignant tumours

DISCUSSION

There was no difference between the duration of primary complaints in patients with benign or malignant tumours

Table 5

	Mean duration of debut symtoms in months	Mean survival in months	Mean observation time in years
Benign tumour	3 4 (min 0 5, max 12)		6 9 (min 0 25, max 29)
Malignant tumour	6 (min 1.25, max 24)	11 5 (min 0 5, max 48)	

Two patients with malignant tumours are still alive However there was no significant difference between the mean duration of debut symptoms in patients with malignant or benign tumours T value 273 5 (limits at 5 per cent 240–355) Wilcoxon test

Acta orthop scand 47, 170-174 1976

PRIMARY TUMOURS IN THE SPINE AND PELVIS IN ADOLESCENTS: CLINICAL AND RADIOLOGICAL FEATURES

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In 34 patients in their two first decades of life with primary bone tumours in the spine and pelvis, the most common benign tumour was histiocytosis X and the most common malignant tumour Ewing's sarcoma X rays were positive in 32 out of 34 cases but of little diagnostic value and primary complaints were without significance The final diagnosis can only be made after a biopsy

Key words bone tumours, Ewing's sarcoma eosinophilic granuloma vertebra plana

Accepted 19 ix 75

Bone lesions in the spine and pelvis in patients in their first two decades of life are very often primary and metastases can, without very great risk, be excluded from the diagnostic considerations (Sharrard 1969) However, it is difficult to make an exact diagnosis on X-ray only (Dahlin 1970, Sissons 1959, Walker 1952) and the X-ray pictures are often regarded merely as a guide for correct biopsy (Dahlin 1970)

The purpose of this work has been to investigate

1 The nature of primary complaints in patients with malignant or benign tumours
2 The primary X-ray findings
3 The histological types and survival rate

MATERIAL AND METHODS

Thirty four patients in their first two decades of life were selected from the files in the Department of Radiology, Municipal Hospital and Orthopaedic Hospital, Aarhus All tumours except for five cases of spontaneously healed vertebra plana were verified by biopsy

The 34 records were reviewed with special reference to duration and nature of the primary complaints and the survival rate, together with

Table 1 Age and sex distribution

	♂	♀
10 years >	11	6
10 years <	9	8

Table 2 Localisation of 34 bone tumours

	Benign	Malignant
Cervical column	1	1
Thoracic column	5	1
Lumbar column	5	3
Sacral column and pelvis	6	12
Total	17	17

Table 3 Classification of 34 bone tumours

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Figure 1. Ewing's sarcoma in the fourth lumbar vertebral body simulating vertebra plana. No soft tissue swelling but some irregularity of the bone structure. This in contrast to Figure 2.

Figure 2. Ewing's sarcoma in the fifth lumbar vertebral body with soft tissue swelling and partial collapse of the body.

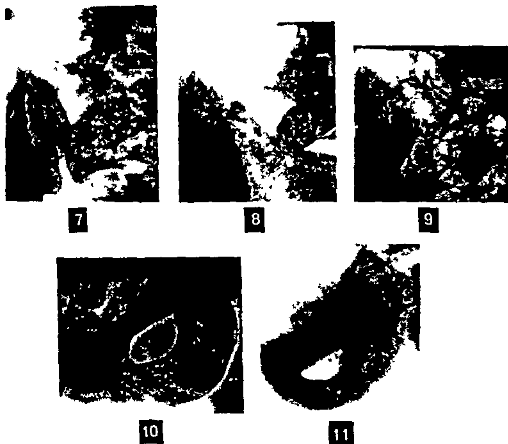
Figure 3. Sclerotic fourth vertebral body due to Ewing's sarcoma.

Figure 4. Vertebra plana in the sixth thoracic vertebral body. Calvé's four criteria are fulfilled. Follow up after 12 years: complete regeneration.

Figure 5. Another case of vertebra plana in the fifth lumbar vertebral body in the regeneration phase. This picture is quite different from Figure 4.

Figure 6. This case of eosinophilic granuloma of the lytic type (Kaye & Freiberger 1969) in the first lumbar vertebral body was erroneously diagnosed as a metastasis from a haemangioma sarcoma because the 5 year-old girl previously had undergone operation for a tumour of this type situated on the back. Complete regeneration after one year.
Compare 1–3 with 4–6.

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Figures 7 and 8 Illustrates lytic lesions in the sacral and iliac bones, one due to Ewing's sarcoma (7) and the other (8) caused by osteogenic sarcoma Both lesions appeared quite similar and permitted no safe diagnosis based on these X-rays even though scanty calcification and new bone formation were seen in the soft tissue in Figure 8

Figure 9 An osteoclastoma in a typical localisation The discreet lesion is primarily lytic and expansive in the right side of the sacral bone

Figures 10 and 11 Two examples of Ewing's sarcoma in the pubic bone In Figure 10 mostly sclerotic and in Figure 11 the sunburst appearance (Dahlin 1970) which is normally characteristic of osteogenic sarcoma

1975) Of the more constant registered physical signs (Table 6) only the X-ray picture was positive in all except two cases (one Ewing's sarcoma and one osteoblastoma) and with a high frequency of malignant tumours (Table 2) localised in the sacral column and pelvis However, even though a bone lesion on X ray was seen in almost every case and sometimes was quite characteristic, the X-ray picture of the most common benign (histiocytosis X) and malignant (Ewing's sarcoma) tumours was quite confusing (Figures 1-6) and it was often difficult to separate these two conditions from each other (Poulsen et al 1975) and also to some extent from other malignant conditions (Figures 7-11) The most













Figure 1. *Ewing's sarcoma in the fourth lumbar vertebral body simulating vertebra plana. No soft tissue swelling but some irregularity of the bone structure. This in contrast to Figure 2.*

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Acta orthop scand 47, 175–180, 1976

OBSERVATIONS IN CHILDREN WITH CONGENITAL DISLOCATION OF THE HIP

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In 111 children who were diagnosed and treated for CDH, certain variables concerning their vital statistics the laxity of their joints and circumstances at birth were recorded It was observed that breech presentation, birth rank one and female preponderance are common traits in children with CDH, who also become taller and heavier than control children Anomalies found at birth or later were more common among these children, in particular inguinal hernia Also joint laxity was more common in these children An increased incidence of CDH was found among siblings

Key words congenital, dislocation, hip, inguinal hernia, joint laxity, foetal presentation

Accepted 8 ix 75

In a report on the effect of early diagnosis it was established that in the city of Malmö almost all cases of congenital dislocation of the hip (CDH) could be diagnosed at birth In a follow-up study on the late results of early treatment it was proved that treatment using the von Rosen splint resulted in completely normal hips Some information included in the case histories and the vital statistics of the children involved in the study on the effect of early treatment will be presented briefly

MATERIAL AND METHODS

During the years 1956–1964 a total of 30,280 live births were recorded in the city of Malmö The incidence of CDH and of undiagnosed cases appears in Table 1

Of 119 cases diagnosed within the first few days of life and treated using the von Rosen splint, there was one child with arthrogryposis, one with meningomyelocele, one with Bonnevie-Ullrichs syndrome and one with cerebral palsy Another child died later on of cardiac failure and three had emigrated leaving 111 typical cases of CDH for the follow-up examination The information was collected at the re examination, from the maternity records and from interviews with child and parents

For the study of joint laxity the same number of age and sex matched control children, taken from the city schools in Malmö, were investigated Joint laxity was estimated according to five variables (Figure 1) It was established whether or not the children were able to

1 Hyperextend the elbow joint more than 10°
2 Hyperextend the thumb and flex the wrist until the thumb touched the forearm.
3 Dorsiflex the fingers and the wrist to make the fingers parallel to the forearm
4 Hyperextend the ankle joint more than 45°.
5 Hyperextend the knee joint more than 10°.

Table 6 Primary laboratory findings

	Benign tumours	Malignant tumours
E S R 10 mm/h	10	10
Elevated alkaline phosphatase	4 (8)	4 (5)
Positive X ray findings	16	16

Figures in brackets indicate the number of patients whose alkaline phosphatase level was not available

common benign lesion in this material was histiocytosis X, including five cases of vertebra plana without biopsy, but the completely benign course and primary X-rays fulfilling Calvé's (1926) four criteria, used by Compere et al (1954) in the diagnosis of eosinophilic granuloma, made the classification reasonable

Taking into consideration the poor survival rate of our patients with malignant tumours (compared with malignant tumours localised to the extremities where a more radical therapy is possible 35 per cent 5-year survival rate (Kaae 1975)), it is essential to have a quick and exact diagnosis and this can in our view only be achieved by biopsy Surgical biopsy in the pelvis and spine is very often an extensive procedure and therefore aspiration biopsy has been used with great success for many years in differentiating between malignant and benign lesions (Dahlin 1970, Ottolenghi et al 1964) and aspiration biopsy should perhaps be the diagnostic method of choice in many cases

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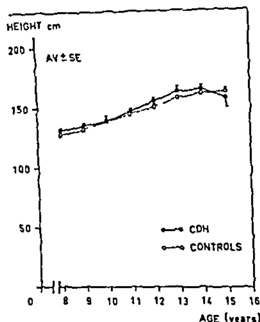


Figure 2 The height of 91 CDH girls compared with 5 4 controls

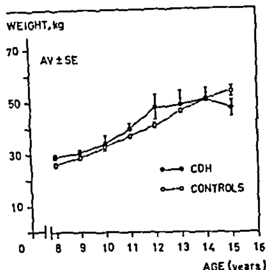


Figure 3 The weight of 91 CDH girls compared with 534 controls

made A number of children of the same generation had been treated after early diagnosis in these families. Five siblings four first cousins and five second cousins. In the previous generation CDH was known in one mother and suspected in a few more cases who had obviously had hip conditions. The CDH children were known to have 136 siblings with an expected risk of CDH of less than one case. Therefore the five cases observed indicate an increased risk, whereas the observations in more distant relatives add

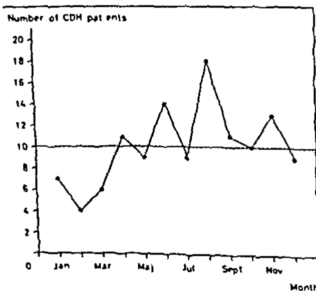


Figure 4 Seasonal variation in birth of CDH children

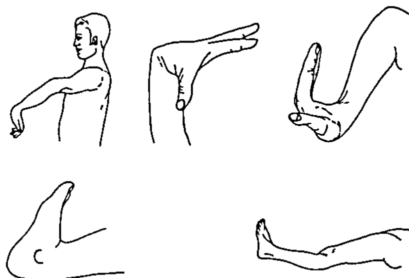


Figure 1 Demonstration of joint laxity

RESULTS

Sex ratio The ratio girls boys in this series was 5 2 1 The average for Malmo is 1 0 1 0

Foetal presentation Thirty-one per cent of the girls and 33 per cent of the boys were born in the breech presentation as compared with the average which is 3 7 per cent in Malmo Of the children born in the breech presentation, 78 per cent were first-born One girl was delivered by Caesarean section One girl was number one of a pair of dizygotic twins (number two, a boy, was unaffected)

Birth rank Sixty per cent of the patients were first-born whereas the average for Malmo is 45 per cent The difference was significant ($0\,01 > P > 0\,001$)

Birth weight The birth weight in CDH girls was 3,457 ± 530 g In a random control sample from Malmo, the birth weight of 100 girls was 3,352 ± 465 g The difference was not significant ($0\,2 > P > 0\,1$)

Height and weight In this study only girls were included The height and the weight were compared with a control sample (Karlberg et al , in preparation) There were significant differences between CDH girls and controls in that CDH girls were somewhat taller and heavier (Figures 2 and 3) Since Willner (1974) has demonstrated that heights in groups of children from various parts of Sweden agree well, the comparison with Karlberg et al is justified

Menarcheal age The menarcheal age in the oldest 19 girls in the CDH series was 12 3 ± 1 4 This means, however that in most girls the menarcheal age is not known and that a late menarche must be expected in some of the remaining individuals Therefore, the difference between these data and data on menarcheal age from a contemporary material (Andersen 1968), 13 3 ± 1 3 years is not necessarily significant

Seasonal variation The incidence of diagnosed CDH in newborns was increased in the period August–November but the deviation in this series was not significant (Figure 4)

Table 1 The incidence of diagnosed and missed cases of CDH in Malmo during the period 1956 1972

	Number	Incidence/1000
Total live births	30 280	
Children with CDH	121	4 00
Missed cases	2	0 07

Heredity An attempt was made to estimate the prevalence of CDH in the families of the CDH children Only an interview with one of the parents was

with those of previous investigators Concomitant malformations have been reported as occurring in CDH children to an increased degree by Record & Edwards (1958), Wynne-Davies (1970) and Bjerkreim & van der Hagen (1974) The data of the present study are not conclusive but taken together with the observations of other investigators they seem to indicate such an increased prevalence The prevalence of inguinal hernia is of special interest Inguinal hernia is extremely rare in girls (Knox 1959) In this series the expected number is very close to zero but four cases of hernia were observed Similar small increases in the prevalence of hernia in CDH children have been observed by Wynne Davies (1970) and Bjerkreim & van der Hagen (1974) Taken together these studies indicate a significantly increased risk of inguinal hernia in CDH girls Wagh et al (1974) found a decreased amount of collagen in the anterior rectus sheath in patients with direct inguinal hernia Similarly Fredensborg & Udén (unpublished data) have demonstrated changes in the collagen of the umbilical cord in children with CDH

It has in the past been demonstrated that there is a relationship between a general joint laxity and CDH Massie & Howorth (1951) were the first to report the combination of general joint laxity and CDH This has been confirmed by Wilkinson (1963) Carter & Wilkinson (1964 b) and Howorth (1965) Wynne-Davies (1970) demonstrated the occurrence of joint laxity also in CDH relatives The previously suggested relationship between general joint laxity and CDH is strongly supported by the findings in the children of the follow up study

Most of the data on CDH children in the present study are in agreement with those of other investigators and merely confirm these findings as well as the identity of the sample One observation however has not been previously presented namely the fact that CDH girls are somewhat taller and heavier than their controls These findings cannot be interpreted at present but might be caused by an earlier maturation in girls born with CDH

ACKNOWLEDGEMENTS

Financial support was obtained from the Swedish Medical Research Council (project no B 75–17X 2737 07C) and the Herman Jarnhardt Foundation

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no further proof to the hypothesis of heredity.

Concomitant anomalies. During the years 1956–1964 a total of 121 children were diagnosed as having CDH. Among these a series of anomalies were recorded (Table 2).

Table 2. Concomitant anomalies in 121 children with CDH

Anomaly	Number Boys	Number Girls
Congenital heart failure	1	
Testes not descended	1	
Meningomyelocele		1
Arthrogryposis		1
Bonnevie Ullrichs syndrome		1
Torticollis		1
Pubertas praecox		1
Inguinal hernia		
bilaterally		2
unilaterally	1	2

None of the conditions listed in Table 2 is expected to occur in more than one per thousand of the population. Therefore, even excluding meningomyelocele, arthrogryposis and Bonnevie-Ullrichs syndrome *the number of anomalies significantly* exceeds the expected. One diagnosis, *inguinal hernia*, is *per se* more frequent than expected.

Joint laxity. In all but one of the variables there was a highly significantly increased incidence of signs of joint laxity in the CDH children (Table 3).

DISCUSSION

The sex ration in this study, 5.2:1, is in agreement with that of earlier investigators. Idelberger (1951) reported a ratio of 5.4:1 based on 45,611 cases and Palmén (1961) a ratio of 4.1:1 in 894 neonatal cases and 5.8:1 in 1,486 mainly late-diagnosis cases. A similar difference in sex ratio between neonatal and late diagnosis was reported by Wynne Davies (1970) and Bjerkreim (1974).

Breech presentation has been referred to as an *environmental factor in the* aetiology of CDH (Record & Edwards 1958, Andren 1961). Several investigators (Wilkinson 1963, 1972, Carter & Wilkinson 1964 a, Fettweiss 1973) claimed that the risk of CDH is particularly increased in breech malposition. The association of breech presentation and birth rank was reported by Record & Edwards (1958), von Rosen (1959) and Andren (1962). If, in the present series, cases born in the breech presentation are excluded, no primogeniture effect remains. This has also been reported by Bjerkreim & van der Hagen (1974).

A few investigators have observed deviations from the average in birth weight *in CDH children* (Record & Edwards 1958, Bjerkreim & van der Hagen 1974, *Artz et al. 1975). However, the investi*gators do not agree as to the direction of this deviation. In the present study the difference was not significant.

As for the concomitant conditions the findings in this study are in agreement

Table 3. Joint laxity in patients with CDH and controls

Joint	CDH children Positive	CDH children Negative	Controls Positive	Controls Negative	
Thumb	65	45	52	58	$P > 0.5$
Wrist	49	61	22	88	$P < 0.001$
Elbow	40	70	6	104	$P < 0.001$
Knee	51	59	15	95	$P < 0.001$
Ankle	34	76	0	110	$P < 0.001$

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SO CALLED RECURRENT PERTHES' DISEASE

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Two cases of "recurrent" Perthes disease are presented and the diagnosis discussed It is concluded that the first episode of hip involvement occurring at an early age was dysplasia epiphysealis capitis femoris

Key words Perthes disease femoral capital epiphysis epiphyseal dysplasia

Accepted 30 ix 75

Very few cases of recurrent Perthes disease have been reported in the literature (Caffey 1945 Kemp & Colmeley 1971 Katz 1973) In addition two separate episodes of avascular necrosis of the same femoral capital epiphysis have been reported in Gaucher's disease (Katz 1967) We have treated two cases for what we believed to be recurrent Perthes disease and the purpose of the present paper is to discuss this diagnosis

CASE REPORTS

Case 1 (Figure 1 a–d) A boy at the age of three years developed a left sided limp The first X rays of the hip in May 1963 were normal The limp persisted and new X rays 4 months later (1 a) showed an irregular ossification centre of the femoral capital epiphysis *interpreted* as Perthes disease at an early stage On examination
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In May 19 0 X rays (1 c) were normal except for some flattening of the capital epiphysis Two years later at 12 years he again began to limp and complained of pain in the left hip Examination disclosed marked reduction in the movements of the left hip Movements were painful and pronounced muscular atrophy of the leg was found X rays (1 d) showed sclerosis fragmentation and flattening of the *capital epiphysis* characteristic of Perthes disease

Case 2 (Figure 2 a–d) A boy aged two and a half years in November 1968 developed a limp on the right side X rays 3 months later (2 a) showed an irregular ossification centre of the right femoral *capital epiphysis* but no sclerosis or fragmentation Our diagnosis was Perthes disease at an early stage He was treated with a plaster abduction brace for 7 months and had a total non weightbearing period of 13 months The radiographic picture improved (2 b) and 4 years after the onset of symptoms the X rays were normal (2 c) Two years later 8 years old he began limping again and complaining of pains in the *right hip* On clinical examination all movements of the right hip were limited X rays taken 1 month after the onset of symptoms were normal but X rays 4 months later (3 d) showed marked involvement of the capital epiphysis characteristic of Perthes disease

DISCUSSION

Two cases of "recurrent Perthes' disease are presented Both were boys and had their first episode of hip involvement be

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tween 2 and 3 years of age. A limp was the main symptom in both cases, and on clinical examination some limitation of movement of the affected hip was found. X-rays in both cases showed irregular ossification of the capital femoral epiphysis, a granular bone structure, but *no sclerosis or fragmentation*. The second episode occurring 9 and 5 years, respectively, after the first one, was characterized by more severe symptoms. Clinical examination revealed marked reduction of movement in the affected hip, and X-rays showed the typical picture of Perthes disease.

When comparing the present two cases with the four cases described previously (Caffey 1945, Kemp & Colmeley 1971, Katz 1973) a similarity is found in that all were boys and all had a mild attack at an early age with an epiphyseal involvement without obvious sclerosis or fragmentation. The second episode was in all cases typical of Perthes' disease.

It thus seems clear that the two separate episodes were different as regards symptoms and radiographic findings, and may well be two different entities. Meyer (1964) among 300 cases of Perthes' disease found 30 cases of dys-



Figure 1 Recurrent Perthes disease in a boy born 1960. The first episode of hip involvement on the left side at 3 and 4 years of age respectively (a and b). Normal left hip except for some flattening of the capital epiphysis at 10 years (c). Typical Perthes disease in the left hip at 12 years (d).



plasia epiphysealis capitis femoris, six of which were combined with typical Perthes disease. He was of the opinion that dysplasia epiphysealis may predispose to subsequent Perthes disease or there may be a common state of susceptibility to the two conditions. In our opinion the first episode in our cases and may be also in the other cases reported earlier as recurrent Perthes' disease may have been dysplasia epiphysealis capitis femoris. In this condition the radiograms show a diffuse granular structure but no sclerosis or fragmentation.

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Figure 2. Recurrent Perthes disease in a boy born 1966. The first episode of hip involvement on the right side at 3 and 4 years of age respectively (a and b). Normal hips at age 7 (c), typical Perthes disease in right hip at 8 years of age (d).



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Figure 2. 'Recurrent' Perthes' disease in a boy born 1966. The first episode of hip involvement on the right side at 3 and 4 years of age respectively (a and b). Normal hips at age 7 (c), typical Perthes' disease in right hip at 8 years of age (d).

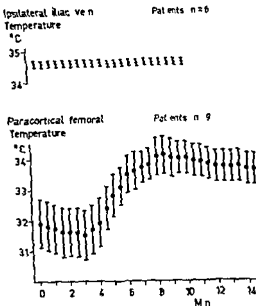


Figure 1 Extraosseous temperature variations during polymerization of acrylic cement in hip arthroplasty

p t) or continually registered (potentiometric recorder)

RESULTS

Juxta cortical measurements

After a delay of 3 minutes the temperature increased from 31 5 ± 0 8° C to 34 1 ± 0 6° C in about 8 minutes The temperature then remained stable up to the end of the period of measurement (14 minutes) (Figure 1)

Venous measurements

No temperature variation was noted during the first 10 minutes following the introduction of the cement (taken as time 0) in the femur (Figure 1)

DISCUSSION

Due to the exothermic polymerization of MM *in vivo* insertion of acrylic cement is suspected to be associated with the production of a large amount of heat Many experiments have been carried out under various experimental conditions in order to evaluate the extent of the thermic reaction (Table 1)

At the sites of measurement spectacular variations previously described were not observed in our study In the ipsilateral iliac vein the temperature did not change during the time of observation It seems that if blood circulation plays a role in heat transportation under clinical conditions this role is strictly local

On the external surface of the upper part of the femur the greatest variations registered were about 3° C which increased the temperature of the zone investigated to 34° C This small increase in temperature as compared with that encountered in preparations of isolated human femur (Öhnsorge & Goebel 1969) may be due to the lower cortical temperature at the beginning of the cementing procedure (31 8 as against 37° C) to possible heat exchange between bone and surrounding tissues and to the role of blood circulation in local thermal redistribution The thermic degradation of organic material must therefore be limited to the inner cortex portion This concept is in agreement with observations made in animal (Homsy 1969 Willse et al 1967) and human studies (Homsy 1969 Charnley 1970) Having demonstrated that the only thermic lesions are localized to the bone cement interface the role if any of exothermic polymerization in inducing cardiovascular reactions and the consequences of thermic lesions remain difficult to appreciate in human subjects

CONCLUSION

No variation of temperature was observed in the femoral vein of patients during polymerization of acrylic cement for hip arthroplasty On the external sur

Acta orthop scand 47, 186–188, 1976

EXTRAOSSEOUS VARIATIONS OF TEMPERATURE DURING POLYMERIZATION OF ACRYLIC CEMENT IN HIP ARTHROPLASTIES

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In order to evaluate the extraosseous temperature variations during polymerization of acrylic cement being used in hip arthroplasty measurements were taken on the anterior aspect of the upper part of the femur and also in the ipsilateral iliac vein No variations were observed in the blood stream On the external surface of the upper femur, the greatest variations were of the order of 3° C The significance of these findings is discussed

Key words methylmethacrylate, hip prosthesis, temperature of polymerization

Accepted 14 x 75

The temperature variations resulting from the polymerization of methylmethacrylate (MM) have been measured in many investigations in animals and *in vitro* (Wiltse et al 1957, Ohnsorge & Goebel 1969, Homsy 1969, Charnley 1970, Jefferiss 1971, Hupfauer & Ulatowski 1972) This exothermic reaction was suspected by Frost (1970) to have cardiovascular effects during the insertion of a cemented endoprosthesis

The aim of this study was to evaluate, under clinical conditions, the extent of the exothermic reaction on the anterior aspect of the upper femoral shaft and in the ipsilateral iliac vein, after insertion of cement in the femur for hip arthroplasty

MATERIAL AND METHOD

McKee Farrar or Moore hip arthroplasties are performed under general anesthesia through a lateral approach The temperature was recorded using a thermistor after the hip had been dislocated

Methylmethacrylate Simplex ® (40 g of powder and 20 cm³ of liquid) mixed with 10 cm³ Isopaque 60 ® is pushed into the femoral medullary cavity after 2 minutes of manual preparation (Charnley & Smith 1968)

The juxta cortical temperature was measured on nine patients The thermistor was inserted through a needle close to the anterior aspect of the upper femoral shaft Intravenous measurements were done by catheterization of the femoral vein in six patients introducing the thermistor up to the sacro iliac joint under fluoroscopic monitoring

The thermistor was connected to a thermometric module (accuracy 0 1° C) and the temperature recorded every 30 seconds (digital out

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NECROSIS OF THE FEMORAL CAPITAL EPIPHYSIS OCCURRING DURING HUMAN GROWTH HORMONE THERAPY

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A girl with growth hormone deficiency developed a necrosis of the femoral capital epiphysis 6 months after the start of human growth hormone treatment The compensatory growth spurt is believed to have caused an insufficient blood supply to the epiphysis resulting in necrosis

Key words growth hormone femur head *epiphysis necrosis*

Accepted 30 ix 75

The treatment of growth hormone deficiency with human growth hormone was first introduced by Raben (1958) Since then several hundreds of patients have had replacement therapy some for more than 10 years Except for the production of growth hormone antibodies with therapy resistance only a few complications have been reported Recently slipped femoral capital epiphysis occurring during growth hormone therapy was reported in three patients (Fidler & Brook 1974, Rennie & Mitchell 1974)

At the Department of Pediatrics, Rikshospitalet, Oslo we have treated 70 growth retarded patients with human growth hormone since 1961, and 12 children have been treated for more than 5 years No therapy resistance because of antibody production has been observed Two boys 12 years of age, with a rapid compensatory growth spurt of 12 cm a year suffered a transitory flexion contracture in the knee joints

The purpose of the present paper is to report on a patient who developed necrosis of the left femoral capital epiphysis

CASE REPORT

A girl (A A born 18 7 55) aged 14 $^{9}/_{12}$ years was seen in the clinic in April 1970 because of failure to grow and mature Her parents and sister were about average height The patient had an infantile appearance doll like face was moderately overweight, and of normal proportions The height was 131 8 cm body weight 35 kg and the bone age was somewhat less than 11 years Growth hormone stimulation tests and a metabolic test with administration of human growth hormone revealed growth hormone deficiency The adrenocorticotropin and thyrotropin secretion was considered normal whereas the luteotropic hormone and follicle stimulating hormone as well as the oestrogen levels in serum were prepubertal The karyotype was normal feminine

From August 1970 the patient was treated with human growth hormone 2 mg (i e 4 i u) intramuscularly three times a week At the start of treatment the height of the patient was 132 0 cm The response to the treatment is given in Figure 1 During the first 6 months of treatment

Table 1 Experiments on the temperature of polymerization of methylmethacrylate

Date	Authors	Type of preparation	Cement	Details	Maximum T° reached
		Human conditions			
1969	Ohnsorge & Goebel	Isolated femur and prosthesis	Palacos	Bone cement interface	
				Greater trochanter	68° C (at 6 min)
				Middle third of the femur	61° C (at 6 min)
				Outer lateral cortex	42 5° C (at 9 min)
1970	Charnley	Cadaveric condition	Simplex	Unknown	12° C
		Animal conditions			
1957	Wiltse et al	Isolated bone in air	Unknown	Unknown	79 5° C
1969	Homsy	Cement in medullary cavity, without prosthesis	Simplex P	Bone cement interface	88° C
		Isolated cement in air			
1969	Ohnsorge & Goebel		Palacos	52 6 g	122° C (interior of the cement)
					92° C (surface of the cement)
1971	Jefferiss		Simplex	Quantity unknown	79 5° C
1972	Hupfauer & Ulatowski		CHW	60 g	121° C
			Simplex	57 g	116° C
			Palacos	55 g	108° C

face of the upper part of the femur the greatest variation registered was about 3° C

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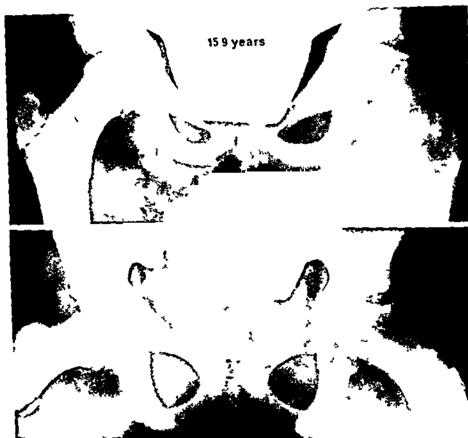


Figure 9 Radiographs of the hips 8 months after the start of growth hormone therapy showing flattening and irregular structure of the left femoral capital epiphysis

and little rebuilding of the femoral head occurred

The incidence of necrosis of the femoral head is relatively high in patients receiving long term corticosteroid treatment in alcoholics and in Gaucher's disease An alteration in the fat metabolism in these patients resulting in fat embolisms has been associated with the necrosis of the femoral head (Brit med J 1972) Human growth hormone has generally been considered to be lipolytic However our patient was treated with a human growth hormone preparation that has been deprived of the lipolytic activity (Trygstad & Foss 1968)

The mechanism of the necrosis of the femoral capital epiphysis in the present patient is not clear In two patients on growth hormone therapy we observed that the growth of the soft tissue did not keep up with the bone growth resulting in temporary flexion contracture of the knee joints We consider that the necrosis of the femoral capital epiphysis in the girl described here was related to her rapid compensatory growth spurt, and an insufficient supply of blood to the epiphysis

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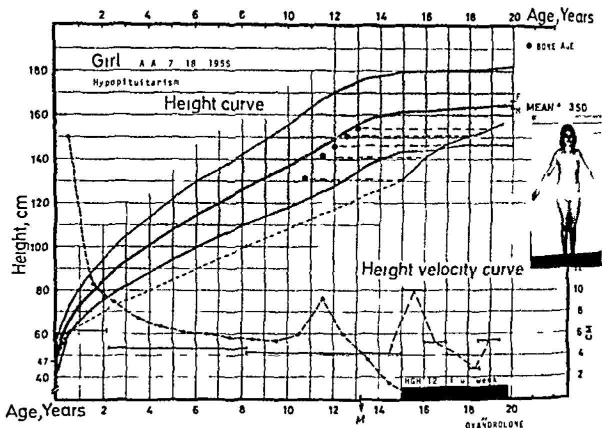


Figure 1 The growth chart of the patient prior to and after administration of human growth hormone (HGH) M denotes the height of the mother and F the percentile height of the father

there was a compensatory growth spurt of 6 0 cm

In January 1971 the patient complained of pain in her left thigh over a period of about fourteen days There had been no previous trauma Clinical examination revealed no limitation in movement of the left hip In April 1971 she started to limp, and after some time she could hardly walk because of pain in the left hip On examination tenderness was found in the left groin and movements of the left hip were markedly reduced in all directions particularly flexion abduction and internal rotation Radiography showed flattening and irregular structure of the left femoral capital epiphysis with a subchondral translucent line (Figure 2) The patient was given non weightbearing treatment on crutches The pain vanished, but the movements of the hip continued to be markedly reduced

A new radiographic examination in August 1972 demonstrated an extensive necrosis involving about three quarters of the femoral head (Figure 3), and there has been little change since then The patient was on continuous human growth hormone therapy After starting the additional treatment with oxandrolone (an anabolic steroid) at the age of 18 5 years a deficient development of pubic hair occurred At 20 years of age there was still no development of her breasts

DISCUSSION

A 15-year-old girl (bone age 11 years) with growth hormone deficiency developed a left-sided hip disorder 6 months after the start of human growth hormone therapy During this period of time she grew 6 cm There had been no trauma The symptoms and the radiograms 8 months after the start of treatment could well be compatible with Perthes' disease However, Perthes' disease is seldom observed in girls of more than 11 years of age (Lauritzen 1975), and the course was also different In spite of a marked necrosis of the femoral capital epiphysis no affection of the metaphysis was seen

Acta orthop scand 47 193–202 1976

THE BASIC REQUIREMENTS AND DESIGN CRITERIA FOR TOTAL JOINT PROSTHESES

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In the past some joint prostheses have been used in which the fundamental requirements of joint replacement were not fully considered This paper lists the basic requirements for joint replacement and thirteen criteria which should be employed in designing a prosthesis to meet these requirements The criteria are discussed in detail The requirements and criteria are important but because some may conflict with others joint design is often a *compromise*

Key words prostheses joints orthopaedic arthroplasty, articulation

Accepted 3 xii 75

In recent years there has been a great deal of activity on the subject of prosthetic joint replacement, and many new implants have ensued Commonly, these devices have been designed by their proponents to overcome specific problems but often the more general requirements of joint replacement have not been fully considered Thus many prostheses have been devised without either a clear understanding of the specifications which must be met or sufficient thought being given to the problems involved This has naturally led to clinical problems with some replacements

The purpose of this paper is to discuss the basic requirements and design criteria in the hope that they will prove useful to others involved in prosthetic joint design

BASIC REQUIREMENTS

Before discussing the design *criteria* for a joint replacement it is necessary to first consider the basic *requirements* The following eight are essential requirements for a joint *arthroplasty*

1 Relief of pain
2 Adequate function
3 Correction of deformity
4 Durability
5 Satisfactory salvage potential
6 Chemical passivity
7 Sterility
8 Appropriate size

In addition the following whilst not being *essential* are desirable

9 Simple operative procedure
10 Minimal operative *trauma*
11 Early mobilisation
12 Not subcutaneous
13 Universality
14 *Convenient* packaging
15 Reasonable cost

Some of these requirements and features *need* no explanation, others are discussed briefly

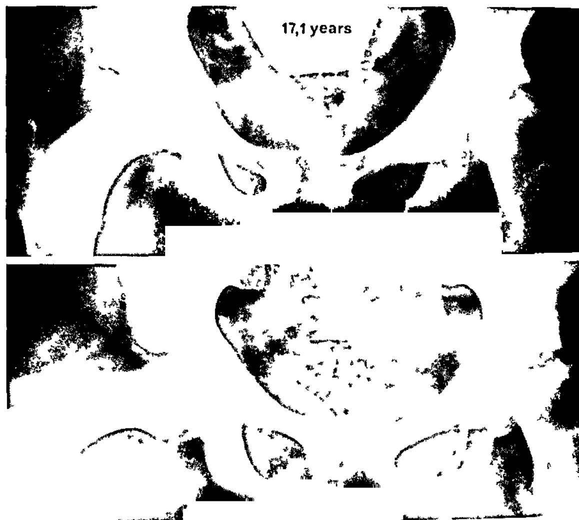


Figure 3. Radiographs two years after the start of treatment show extensive necrosis of the femoral head.

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Figure 1 Oblique X ray of a Liverpool knee prosthesis Near normal articulation and accurate insertion ensured by special instruments give good stability and range of movement with minimal operative trauma (in this view the plastic components are invisible)

than sufficient to provide adequate function If movement in a prosthesis is normally limited by a mechanical interference then unacceptable stresses may be imposed on the implant or its fixation

(c) The components of the prosthesis *should only* articulate with each other and not with bone or cartilaginous parts of the joint

(d) The locus of the centre of rotation should closely approximate to that of the normal joint so that normal muscle and ligament actions may be restored as for example in the Liverpool knee (Figure 1) described by Cavendish & Wright (1974) Some designs of a bicondylar knee prosthesis such as that pioneered by Gunston (1971), use semicircular femoral components and the locus of the centre of flexion follows an unnatural path, but normal ligaments are retained for joint stability The result is that, with an implanted position which gives good semiflexed stability, ligament tightening can prevent full extension, particularly if the cruciate ligaments are intact

Stability

The stability of the normal joint derives from a proper relationship between the shape of the articular surfaces, the muscles acting about the joint, and the length and position of ligaments Examples are the medial and lateral ligaments of the elbow and the collateral and cruciate ligaments of the knee The manner in which they also control knee articulation is described by Girgis et al (1975) It is invariably erosion of the joint surfaces, loss of integrity of these ligaments and perhaps loss of muscle tone due to inactivity which cause instability of the diseased joint In many cases preservation of the ligaments and reconstruction of the articular surfaces will restore adequate stability Exceptions are the rheumatoid shoulders, fingers, and other joints in which there is severe involvement of soft tissues in the disease process In these circumstances it is necessary to design intrinsic stability into the prosthesis otherwise prolonged postoperative immobilisation of the joint is required Examples of inherently stable joints are the Leeds shoulder described by Reeves et al (1974) and the Liverpool shoulder (Figure 2)

Loading

It is clearly necessary that the implant be capable of supporting the loads to which it will be subjected within the body Direct measurements of these loads

Durability implies that neither the prosthesis nor the adjacent bone will fail through fracture or excessive wear Ideally a prosthetic joint should have a useful life at least equal to the remaining life span of the patient, and in elderly and relatively inactive patients this might be attained quite easily However, in the younger and much more active patient, with a longer life expectancy, the implant may wear out, in which case the facility to replace the failed parts would be useful An implant life of at least 15 years is desirable

In the event of failure due to infection, technical errors, or mechanical causes it must be possible to carry out a salvage procedure This must be achieved without excessive limb shortening whether the salvage involves the use of another prosthesis, a pseudoarthrosis, or arthrodesis of the joint

Chemical passivity implies that the implant must not corrode in the body, and neither the implant nor any wear particles which may be produced should be toxic or invoke an adverse tissue reaction

A simple operative procedure is desirable to reduce the risk of surgical error, minimise operative time and make the procedure available to less experienced surgeons Where needed special purpose instrumentation should be available

Minimal operative trauma will reduce postoperative complications and recovery time If the joint is immobilised during the formation of a new capsule and soft tissue healing, these may severely limit articulation until stretched

A subcutaneous implant should be avoided whenever possible, for wound healing may be retarded and the risk of implant infection increased

Universality, i e a minimum number of necessary implant variants, is desirable for technical and economic reasons Ideally a single implant configuration suitable for bilateral use and sized to suit *all adult patients* is preferred, as the risk of an inappropriate implant being used is eliminated, and a lower unit cost will be possible

A convenient packaging will allow the implant to be presented at operation clearly marked, sterile and undamaged

Cost is an important consideration if the prosthesis is to be widely available This is especially true for finger joint replacement where up to eight similar prostheses might be used in a single patient

DESIGN CRITERIA

We consider that there are thirteen criteria which should be employed in designing a prosthesis to meet the basic requirements These are

1 Appropriate articulation
2 Good stability
3 Adequate strength
4 Good fixation
5 Correct choice of materials
6 Low friction forces
7 Acceptable wear rate
8 Good salvage potential
9 Fail safe feature
10 Standardisation
11 Sterilisation
12 Cost effectiveness
13 Surgical instrumentation

Appropriate articulation

Four factors are important in articulation

(a) The degrees of freedom should be appropriate to the joint being replaced For example, we consider that a simple hinge is not appropriate for use in the metacarpophalangeal finger joint, as *two* degrees of freedom are required, not one

(b) The range of movement need not necessarily be as great as in the normal joint but it must be more



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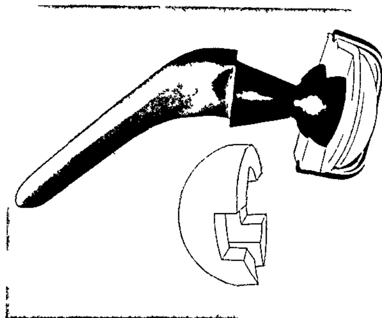


Figure 2 The Liverpool shoulder prosthesis which combines a full range of articulation with controlled inbuilt stability. A protective cap (shown below) protects the bearing surface of the metal scapular component and ensures correct orientation of the plastic humeral component during insertion. The plastic parts have been outlined for clarity of illustration

are not usually possible although Rydell (1966) obtained the walking forces in the hips of two subjects by implanting strain gauged prostheses. His results showed peak forces of about 3.5 times body weight. Because of the technical and ethical difficulties involved with such tests, indirect load measurements may have to be used. For example Paul (1969) using measurements from a foot force plate, cinematography and myography calculated that typical hip forces during normal walking peaked at about four times body weight. Indirect measurements have also been made of knee forces (Morrison 1968) and similar work on other normal and prosthetic joints (McGrouther 1974) is presently being conducted at various centres. Several workers including Seireg & Arvikar (1975) have shown that static analyses can be used to estimate the order of forces acting on joints. Information on loading thresholds may also be inferred from a measurement of those forces which will disrupt the soft tissues about cadaveric joints. For example Reeves (1968) in tests on 110 cadavers measured forces to tear the capsules of shoulder joints. These results could be used for assessing dislocating forces.

Fixation

Adequate fixation of the prosthesis is necessary for two reasons. Firstly to prevent unwanted movements between the implant and bone and secondly to transmit joint loads into the bone in such a way that they will not cause excessive stresses in bone or implant. This requirement can be met by ensuring a good surface contact between prosthesis and bone over a sufficiently large surface area. It is most readily achieved by the effective use of bone cement which also has the advantage of giving good initial fixation and permitting early mobilisation as reported by Charnley (1970). It should be emphasised that acrylic bone cement is a filling agent and *not* an adhesive. It follows that the prosthesis and the bone must have suitable surface configurations to key the cement. The shape should be such that it will ensure adequate distribution of the cement and also force it into the interstices of the cancellous bone.

In designing the fixation one should take into account the natural load distributing structures of the bone. Several workers including Milch (1940) and Seireg & Arvikar (1975) using photoelastic models or finite element analyses

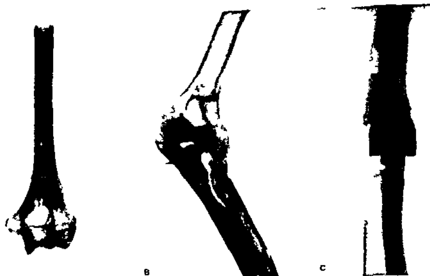


Figure 3 (a) Anterior posterior X ray of the distal end of the humerus showing the trabeculae of the supracondylar ridges

Figure 3 (b) X ray of a semi flexed elbow joint with a Liverpool prosthesis implanted This is an example of the use of natural load bearing structures for fixation (in this view the plastic component is invisible

Figure 3 (c) X ray of a Shiers elbow joint prosthesis showing the long intramedullary stems typical of some hinged prostheses

have shown that stress trajectories in the proximal femur bear a remarkable resemblance to the trabecular patterns On the assumption that this is also true of bone adjacent to other joints, a study of these trabecular patterns should give a good indication of the optimal fixation design For example Figure 3 a is an anterior/posterior X ray of the distal end of the humerus in which elbow joint forces are naturally transmitted from the trochlea to the shaft by means of the trabeculae of the supracondylar ridges In designing an elbow prosthesis we preferred to make use of these natural load bearing structures for fixation (Figure 3 b) rather than to bypass them with a long intramedullary stem as used in the Shiers prosthesis (Figure 3 c)

Consideration must be given to the viability of bone adjacent to the prosthesis for whilst living bone tends to remodel, accommodating stresses imposed upon it and improving fixation dead bone may fail by a fatigue mechanism which could result in loosening of the implant The viability of the bone may be jeopardised either by avascular necrosis or by thermal damage resulting from heat generated by the cement whilst hardening These difficulties are best avoided in three ways Firstly, the implant design and the surgical procedure which it necessitates should not seriously disturb the existing blood supply or impair the revascularisation of the remaining bone Secondly, the quantity of cement required for satisfactory fixation should be minimised Thirdly, the design should avoid the necessity of using cement on small fragments of bone unless they have a good independent blood supply When using a tourniquet during joint replacement, some surgeons attempt to minimise thermal damage by releasing the tourniquet during the critical setting period of the bone cement, thus providing a cooling flow of blood

Table 1 Typical mechanical prop

Material	Ultimate tensile strength (U T S) $N/m^2 \times 10^7$	Fatigue limit $N/m^2 \times 10^7$	Modulus of elasticity $N/m^2 \times 10$
Stainless steel 316 S16 & S17, 317 S16	65–100	28–30	20
Co – Cr – M cast alloy	69	30	20
Co – Cr – W wrought alloy	154	49	23
Titanium wrought	40–67	17–30	11
Polymethylmethacrylate	7	0 68	0 3
Polymethylsiloxane	0 5		up to 0 001
Ultra high molecular wt polyethylene	2–4		0 055 0 0
Human bone (wet) a) cortical	6 5–11 7 (Compressive)		1 1 2 3
b) cancellous	0 03–1 59		0 003–0 1

Materials

There are six basic requirements for joint implant materials They must have adequate strength to carry the loads, be non toxic, not corrode in the body nor produce the adverse tissue reaction described by Williams (1975) Bearing surfaces should have low friction and good wear characteristics The materials most commonly used are the four metals and three polymers listed below

Wrought Austenitic stainless steel (types 316 S16, 316 S12 and 317 S16)

Cobalt-chromium-molybdenum cast alloy (known variously as Stellite, Vinertia, Vitallium, Alvium, etc)

Cobalt-chromium tungsten wrought alloy (also known as wrought vitallium)

Pure Titanium and titanium alloy

Ultra high molecular weight polyethylene (UHMWP, incorrectly known as high density polyethylene or HDP)

Polymethylmethacrylate cement (known as acrylic bone cement)

Polydimethylsiloxane (known as silicone rubber or Silastic)

The mechanical properties of these materials and those of bone are given in Table 1 It is the fatigue limit (i e the stress to which the material may be indefinitely cycled without failure), which should be used in the design calculations rather than the ultimate tensile strength (U T S)

Stainless steel is especially useful during the development phase of new prostheses because it can be forged and is readily machined Disadvantages are that for implants it may not be welded or cast Cobalt-chromium-molybdenum cast alloy, however, whilst being more difficult to machine, can be cast to fine limits and is therefore generally more suitable for the commercial production of implants with complex shapes Wrought cobalt-chromium-tungsten alloy may be used as an alternative to stainless steel where cold working and higher strengths are required Titanium has the disadvantage of having poorer bearing properties but Williams (1975) indicated its superior corrosion resistance Williams & Roaf (1973) emphasise the need for great care to avoid galvanic corrosion when more than one metallic component is used in an implant Silicone rubber has limited application in joint prostheses, its main use being confined to flexural elements in finger joints

Friction

The co-efficient of friction of all these materials is an order of magnitude greater than that of articular cartilage

mmon mplant mater als and bone

Yield stress $N/m^2 \times 10^7$	Ductility (plastic deformation) % elongation	Density g/ml	Comment
28 97	9–45	7 9	BS 3531 (1968)
49	8	8 3	BS 3531 (1968)
105	9–60	9 2	BS 3531 (1968)
28 54	1? 35	4 5	BS 3531 (1968)
7	5	1 2	Beadle (1970)
0 83	up to 600	1 17	Williams & Roaf (1973)
2 1	up to 800	0 935 m n	At 23 C
	0 36–3 29	1 6–2 1	Evans (1973)
	0 01–0 29	1 39 2 19	Evans (1973)

Duff Barclay & Spillman (1966) confirmed Charnley's early work in which he showed that UHMWP against metal gave the lowest friction of the materials listed above Although the patient may not be aware of friction forces on his prosthesis they have to be transmitted across the implant/bone interface and therefore should not be ignored for high friction loads could endanger implant fixation

Wear

In metal metal prostheses such as the McKee Farrar hip finely divided metallic wear particles are produced These particles impregnate the tissues around the arthroplasty and can cause a tissue reaction Systematic absorption of metal has been reported by Coleman et al (1973) and cobalt has been shown to be carcinogenic in experimental animals (Heath et al 1971) however there have been no published cases of sarcoma in man attributed to this cause

The best combination of *currently* available materials for joint replacement are considered to be cobalt-*chromium* molybdenum alloy or stainless steel in conjunction with ultra high molecular weight polyethylene Duff Barclay & Spillman (1966) showed that the combination caused minimal wear to the metal component The remarkably good bearing properties of this plastic against metal are in part due to its ability to plastically deform under load which improves congruity between the sliding surfaces and reduces bearing pressures Because of this deformation the initial surface finish on the plastic is not critical However the plastic deformation can result in microscopic flowing of the material into bearing surface imperfections of the metallic component so that relative motion could result in high shear stresses and a high wear rate of the plastic component Good surface finish and avoidance of surface discontinuities on the metallic component are therefore essential When using soft and *hard* materials as opposing bearing surfaces it is usual engineering practice to make the concave surface of the softer material This not only *minimises the effect* described above but is usually consistent with placing the weaker material in the less stressful situation

Wear or geometric changes in joint prostheses are usually confined to the plastic components and these should be replaceable if bearing life is in doubt *As UHMWP* is transparent to X rays it is necessary to embed metallic X ray markers in the plastic in order that its

position and wear status may be determined after implantation It is less satisfactory to rely on radio opaque additive to cement, although this is useful for delineating cement boundaries

It is impossible at present to confidently predict the life expectancy of a new design of prosthesis *In vitro* tests *cannot reproduce the load and* environmental conditions of the implanted joint However, such tests may be of use in placing various prostheses in order of mechanical merit, thus preventing some unsatisfactory devices reaching clinical trial The actual useful life of a prosthesis can only be determined from clinical experience

Salvage potential

It must be possible to salvage the joint in the event of failure Clearly the smaller the amount of bone removed in the initial operation, the greater the choice of procedures during a second intervention Cemented implants with long intramedullary stems can be particularly difficult to remove

Fail safe

In case of extraordinary loads being applied, as in trauma, it is an advantage if the prosthesis can luxate, otherwise fracture of the bone, the implant or its fixation may occur Most hip prostheses are luxatable and examples of other luxatable joints are shown in Figures 1, 2 and 3b Further examples are described by Gunston (1971), Lettin & Scales (1972) and Neer (1974) However, many prostheses have been designed which are incapable of dislocation such as that shown in Figure 3 c and those described by Shiers (1960), and Reeves et al (1974)

Standardisation and cost effectiveness

To achieve universality the designer should aim at producing one size and configuration of prosthesis for either side of any patient, and if possible, a simple geometric shape which can be economically manufactured For example this has been achieved with the elbow (Figure 3b) by avoiding intramedullary stem fixation and by sacrificing the conjunct rotation of the natural joint Universality has been implemented in different ways in other joint prostheses

Sterilisation

The metal parts of prostheses may be steam autoclaved and thus easily sterilised Heat sterilisation is not satisfactory for UHMWP which has a melting point in the range 130–140° C (close to steam autoclave temperature) and a heat distortion temperature of 70–80° C at which stress relieving and dimensional changes can occur

There are various methods for sterilising plastic components, but of these gamma radiation of at least 2 5 M rad is widely used and this method is also suitable for sterilising metallic components As this process must be carried out at specialist centres, implants which contain plastic components should be supplied pre sterilised

Handling and protection

The bearing surfaces of prostheses are necessarily manufactured to close tolerances and fine finishes Protection of these surfaces must be provided to prevent damage during handling as this could adversely affect the function or life of the implant Consideration of the packaging and handling facilities should be made during the design of a prosthesis It is an advantage if the design provides for protection of these surfaces during handling and implantation, as in the Judet Monoblock hip and the Liverpool shoulder prosthesis (Figure 2)

Instrumentation

Special purpose instrumentation may be necessary to ensure accuracy of insertion of the prosthesis, or for the convenience of the surgeon The need or otherwise of such instrumentation should be considered together with the intended operative procedure throughout the design phase of the prosthesis

Prostheses which do not require special instruments are at an advantage provided that the surgical procedure or their implanted function are not compromised However, in some circumstances elaborate instruments which ensure accuracy or serve to reduce the operative trauma are justified

CONCLUSIONS

There is much scope for optimisation of designs using established bio-compatible materials for which a wealth of knowledge and experience has already been accumulated

However, some total joint replacements have been ill considered and are not likely to give good clinical results We have avoided direct reference to these On the other hand some designs have found wide acceptance with high clinical success, the outstanding example being the low friction hip arthroplasty with cemented fixation as pioneered by Charnley

In presenting the basic requirements and design criteria we hope that this paper will achieve two objectives Firstly, to highlight the important requirements and criteria for those involved in joint design Secondly, to give other clinicians a basis on which to judge the relative merits of various prostheses

The design of total joint replacements is of necessity a compromise because some of the requirements and criteria may conflict with others It is therefore important to clearly understand all the requirements if the best compromise is to be made Because of these conflicts it is likely that different teams will place emphasis on different aspects of the requirements and will thus arrive at alternative prostheses which may prove equally effective in treating patients

We firmly believe that prosthetic joint design should be a team effort, and the team should consist of both surgeon and engineer In the final analysis, even with satisfactory joint designs, the clinical results will depend upon the surgeon's skill For example, insufficient cement could jeopardise fixation, and excess cement limit the range of articulation or cause gross wear if cement particles are introduced between the bearing surfaces It is therefore desirable that designers devise joint prostheses and instruments that will minimise the surgical difficulties A particular design is unlikely to be suitable for all cases and so it is necessary to clearly define the limitations of its use

The designers are invariably faced with gaps in their knowledge These must be bridged initially by experienced judgement or even intuition and consolidated by a process of empirical development Although it is impossible from *in vitro* tests to accurately predict the life of a newly designed prosthesis a good estimate of its viability may be made from a critical comparison with others of proven clinical success

The criteria presented are not intended as firm rules, but rather as a statement of the design philosophy which we have developed over recent years Other workers may feel that different criteria are equally or more important Accepting this, we feel that there may be many satisfactory solutions to any one problem with much scope for inventive flair and the lateral thinking described by de Bono (1972)

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Acta orthop scand 47 203 208 1976

BILATERAL TOTAL HIP ARTHROPLASTY· A SIMULTANEOUS PROCEDURE

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Fifty patients undergoing bilateral total hip replacement as a simultaneous procedure at the Indiana University Medical Center were compared with 50 patients undergoing unilateral total hip replacement There was an increase in phlebitis and myositis ossificans in the patients undergoing bilateral total hip replacement and while their range of motion was less there was no difference in mortality with one death in each group The hospital time for patients in the bilateral group averaged 1 week longer than for those with unilateral hip replacement The operating time and blood loss in patients of the bilateral group was approximately twice that of patients in the control group There have been no infections as yet in the bilateral group On the basis of these preliminary results we can consider bilateral total hip arthroplasty feasible although it carries a slightly increased risk.

Key words bilateral total hip arthroplasty simultaneous hip joint

Accepted 4 xii 75

Although bilateral hip disease is now successfully treated by total hip replacement (Charnley 1970 Freeman 1970, Harris 1972 Jaffe & Charnley 1971, Morris & Nicholson 1970 Welch & Charnley 1970) verbal opinions differ as to whether both hips should be replaced in a single operative procedure If a controlled study comparing patients with bilateral total hip replacements at a single operation and patients with unilateral total hip replacements were to demonstrate little or no increase in morbidity, mortality or the duration of postoperative rehabilitation with the simultaneous procedure then that operation would seem to be a reasonable choice for patients with bilateral hip disease This paper reports on our experience with bilateral hip replacement in one setting

METHODS AND MATERIALS

At the Indiana University Medical Center 50 consecutive patients with bilateral total hip replacements at a single operation were compared to a control group of 50 consecutive patients with unilateral total hip replacements Patients were matched as closely as possible with regard to age etiology of hip disease type of total hip prosthesis used and length of follow up Since the beginning of this study all patients for whom bilateral total hip replacement was judged the proper surgical approach underwent the bilateral procedure under one anesthetic Individuals were not excluded from this study because of age severe flexion con

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Operating room time

The mean operating room time (anesthetic time) for patients undergoing a bilateral total hip replacement was 3 hours and 5 minutes (range 2 hours to 4 hours and 30 minutes) This includes the 20 to 30 minute changeover time The mean time for unilateral total hip replacements was 1 hour and 35 minutes (range 1 hour to 3 hours)

Patients with previous hip surgery (i e cup prosthesis, and especially displacement osteotomy) accounted for ten of the bilateral hips and were all procedures on the longer side of the mean time, as were the six unilateral previously-operated hips There is no question that a previously operated hip prolongs the operating time

Type of anticoagulant and method of use

In the bilateral group, 13 patients received 5 000 units of Heparin subcutaneously the night before surgery and every 12 hours postoperatively Eight patients received 5,000 units of Heparin 2 hours preoperatively and every 12 hours postoperatively Twenty eight patients were treated with Coumadin and one patient with low molecular weight Dextran In the unilateral group seven patients received 5,000 units of Heparin the night before surgery and every 12 hours postoperatively Seventeen patients received [illegible]

Coumadin and one patient not anticoagulated

Blood received

The mean amount of blood replaced in surgery for patients in the bilateral group was six units (range two to eleven units) The mean amount of blood received either in the recovery room or on the ward was one unit (range from zero to five units) Twenty three patients in the bilateral group received no postoperative blood transfusions In the unilateral group, the mean blood received in surgery was three units (range zero to five units) In this group of patients 35 received no postoperative blood transfusions

Rehabilitation

All patients in both groups, regardless of the type of prosthesis, were sent to the Physical Therapy Department, 3 to 4 days postoperatively They were begun on ambulation training beginning with tilt table activities and progressed to ambulation bearing full weight with external support This external support (walker or crutches) was continued for 6 weeks Use of a cane was then encouraged as long as a limp persisted

The mean hospital stay for the patients undergoing bilateral total hip replacements was 21 days (range 10 to 42 days) The mean hospital stay for patients undergoing unilateral total hip replacement was 15 days (range 10 to 43 days)

In general, there were more complications with patients in the bilateral group than in the unilateral group (Table 2) The incidence of clinical thrombophlebitis among the bilateral patients was 12 per cent (one leg in each of six patients) or 6 per cent if related to the number of hips operated The incidence of clinical thrombophlebitis in the control group of unilateral total hip patients was 2 per cent In a recent article from our institution, 380 consecutive total hip replacements were evaluated as to the effect that Warfarin, low-dose Heparin or Hydrocortisone have in the prevention of clinical thromboembolic disease (Ritter et al 1975) In 220 unilateral hips there was an average clinical thromboembolic incidence of 6 per cent (14 patients) In the 80 patients (160 hips) undergoing the simultaneous bilateral operation there was an overall clinical thromboembolic problem of 14 per cent (11 patients)

fracture, etiology and severity of the hip disease or underlying medical problems All procedures were performed or supervised by the senior author They were compared in terms of the following (1) length of hospitalization and operating room time (2) type of anticoagulant used and method of administration (3) units of blood transfusions to the patient in the operating room in the recovery room and on the ward and (4) follow up evaluations after a minimum of two years All hip patients at the Indiana University Medical Center are coded pre and postoperatively (in accordance with the Hospital for Special Surgery hip evaluation) as regards hip pain walking ability range of motion and functional capacity (Wilson et al 1972) The senior author and head surgical nurse were scrubbed for all cases All patients were prophylactically treated with Keflin or Cleocin for 10 hours preoperatively and 5 days postoperatively All operations were performed under general normo tensive anesthesia with the patient in the supine position and a sandbag under the affected hip and in an operating room equipped with a horizontal wall less laminar air flow system A straight lateral incision for removal and transposition of the greater trochanter was used in all procedures regardless of the type of prosthesis to be used Instruments for the total hip replacement were divided into four groups and used sequentially throughout the case Each group of instruments was placed in a surgical basket The entire basket was placed on the operating room table so that the surgeon could select the proper instrument at the appropriate time from the basket

Prior to a bilateral procedure two back tables (2 × 4) with draping equipment were set up and placed next to the laminar air flow unit One table was left covered during the first hip procedure for later use during the opposite hip procedure As the skin sutures were begun on the first hip the scrub nurse and second assistant broke scrub While the skin was being closed this portion of the team re scrubbed and re gowned As soon as the dressing was applied to the first hip the preparation of the second hip was begun by the second assistant The surgeon and first assistant re scrubbed and re-gowned The second hip was then draped appropriately The time from the last skin suture of the first hip to the skin incision of the second hip was approximately 20 to 30 minutes

RESULTS

The mean age of patients undergoing bilateral total hip replacement was 63 (range 28 to 81) The 28 year old patient had juvenile rheumatoid arthritis and the 81-year old had bilateral osteoarthritis The mean age of the unilateral total hip replacement patients was 65 (range 37 to 85) The 37-year old patient had rheumatoid arthritis and the 85 year old had osteoarthritis

The etiology of the hip diseases is illustrated in Table 1 In the bilateral group there were 58 Charnley prostheses (29 patients), 40 Charnley Mueller prostheses (20 patients) and two McKee Farrar prostheses (one patient) In the group having unilateral total hip replacements there were 28 Charnley prostheses 17 Charnley Mueller prostheses and five McKee Farrar prostheses

Table 1 Type of disease prior to surgery

Bilateral (100 hips)		Unilateral (60 hips)	
Disease	No of hips	Disease	No of hips
Osteoarthritis	77	Osteoarthritis	38
Rheumatoid arthritis	8	Rheumatoid arthritis	3
Ankylosing spondylosis	4	Failed unipolar prosthesis	3
Failed cup arthroplasty	4	Avascular necrosis	2
Avascular necrosis	3	Failed cup arthroplasty	2
Gouty arthritis	2	Ankylosing spondylosis	1
Septic dislocation	2	Non union secondary to pinned fracture	1
Failed prosthesis	2		
Failed total hip	1		
Failed osteotomy	1		

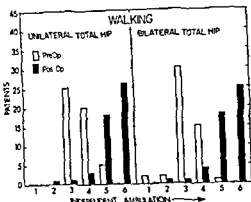


Figure 2 Preoperative walking ability as contrasted with postoperative walking ability in unilateral and bilateral total hip patients Number one on the abscissa equals patient is bedridden Number six equals no limp

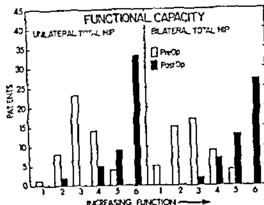


Figure 4 Preoperative functional evaluation as contrasted with postoperative functional evaluation in unilateral and bilateral total hip patients Number one on the abscissa equals patient is disabled and requires assistance Number six equals full physical labor and patient can participate in all sports or do heavy house work

not only for the hip involved with the disease, but for the contralateral hip as well

DISCUSSION

Many older patients would benefit from a bilateral reconstructive hip procedure and a total hip replacement seems the operation of choice However, use of a general anesthetic places a serious stress on the vital systems of these patients If such an undertaking could be performed under a single anesthetic with no increase in mortality and an awareness of the potential increase in complications, it would seem to be in the best interest of the patient to do so An increase in morbidity or mortality is particularly disconcerting for a surgeon and these potentials must be weighed in the decision as to whether both procedures should be performed under a single anesthetic We have been satisfied with bilateral total hip replacement under a single anesthetic Patients undergoing bilateral total hip replacement did have an increased morbidity, but an increase in complications with such a procedure is to be expected The complication of thromboembolic disease continues to be a major problem Even though there is a great difference between our control and study group it is only double when evaluating a large consecutive series (Ritter et al 1975) We have, however, had no increase in operative or postoperative mortality

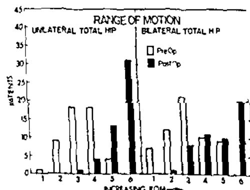


Figure 3 Preoperative range of motion as contrasted with postoperative range of motion in unilateral and bilateral total hip patients Number one on the abscissa equals ankylosis with deformity Number six equals almost normal range of motion

In general the study group did as well

Table 2

Postoperative complications	Unilateral	Bilateral
Phlebitis	1 patient	6 patients (one leg each)
Myositis ossificans	None	8 hips in 5 patients
Pulmonary embolus	1 patient	3 patients
Dislocation	2 patients	3 hips in 3 patients
Urinary tract infection	None	3 patients
Death	1 patient (2° to P E *)	1 patient (2° to P E *)
Sacral decubiti	None	1 patient
Non union of greater trochanter	None	1 hip
Heel sores	None	Bilateral 3 Unilateral 0
Wound hematoma	1 patient	Bilateral 1 Unilateral 3
Femoral artery embolus	None	1 hip
Fusion	None	1 hip secondary to Myositis ossificans
Pneumonia	None	1 patient
Wound infection	None	None

* Secondary to pulmonary emboli

The incidence of radiographically detectable myositis ossificans in the bilateral group was eight hips in five patients There was no myositis ossificans in the unilateral group To date there are no known infections in the bilateral patients Therefore, an infection in a unilateral total hip replacement was not used in the control group

Postoperative evaluation

The Hospital for Special Surgery hip evaluation form was used to determine postoperative results (Wilson et al 1972) Of significance, is that the bilateral patients had no detectable difference in postoperative results when comparing one side with the other

Table 3 shows that there is little difference in the years following There was little difference in pain relief, walking ability and functional capacity between the two groups as shown in Figures 1, 2 and 4 However, there was a difference in the range of motion (Figure 3) In the study group this difference was clearly seen in the patients with myositis ossificans It seems that the myositis ossificans interfered with the range of motion

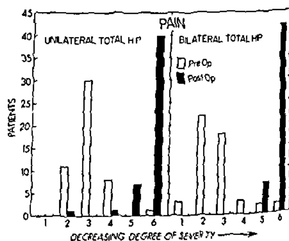


Figure 1 Preoperative pain as contrasted with postoperative pain in unilateral and bilateral total hip patients Number one on the abscissa equals severe pain patient cannot sleep or rest and a strong analgesic is required Number six equals no significant pain

Table 3 The number of years each patient has been followed postoperatively

	Unilateral	Bilateral
2 years	26	26
3 years	19	18
4 years	4	6
5 years	1	0

Acta orthop scand 47 209-213 1976

TREATMENT OF FRACTURES OF THE FEMORAL NECK BY PRIMARY ARTHROPLASTY

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A total of 163 patients with fracture of the neck of the femur in the acute stage were treated at the Orthopaedic Clinics of Harnosand and Östersund, between 1963 and 1970, by insertion of Moore's endoprosthesis The patients were either above 70 years of age or were younger patients with debilitating diseases The patients were followed up clinically for up to 9 years after operation, and 133 of them until death (average 3 4 years) The mortality within 6 weeks postoperatively was 9 per cent, other complications not producing late sequelae were seen in 8 per cent and complications producing late sequelae in 5 per cent A good functional result was achieved in 95 per cent of those surviving the immediate postoperative course A careful review of a sample of the patients showed that 77 per cent were without pain and 93 per cent could manage activities of daily living

Key words femoral neck fractures surgery, arthroplasty, follow up studies hip joint joint prosthesis, methods, postoperative complications, prognosis

Accepted 11 xi 75

It was once widely believed that when Smith-Petersen (1931) published his method of reposition and nailing all the problems associated with the treatment of fracture of the femoral neck were solved However late complications, especially necrosis of the femoral head and pseudarthrosis, continued to appear These fractures so common in elderly patients, among whom late complications arise in up to 50 per cent of cases (Table 1), constitute a heavy burden on the community and on the hospital services

Despite various technical modifications of the method, the use of different types of nails, and improved after-care, reposition and nailing have not resulted in any advance in the treatment of femoral neck fractures (Banks 1962)

Moore's self locking endoprosthesis was devised in 1951 In the Departments of Orthopaedic Surgery at Harnösand and Östersund, this prosthesis has been used routinely since the beginning of the sixties as the primary treatment of fresh medial fractures of the femoral neck Now that a fairly large series has accumulated an assessment has been made of the complications and late results of the method

MATERIAL AND METHODS

Series I comprises 163 patients treated in the Departments of Orthopaedic Surgery at Härno-

as the control group, particularly following discharge, as noted in their postoperative hip ratings (Figures 1–4) Figure 3 reveals there is a difference in range of motion between the two groups which we feel is related to two factors Firstly, the preoperative motion in the bilateral group was worse to begin with and secondly, there were more hips affected with myositis ossificans Not only did the ectopic bone limit the hip involved, but the motion of the contralateral hip as well when not involved

It is our feeling, therefore, that if a select team can be developed, whereby the operating time can be kept to a minimum, patients requiring bilateral total hip replacement will benefit from having this done as a simultaneous procedure, rather than in an operation of two stages, as long as the surgeon and patient are aware of the increased morbidity

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Table 5 Total result (Series I)

	No	Per cent
Died	15	9
Complications wiht late sequelae	8	5 4
Good – otherwise healthy	110	85 6
– otherwise disabled	30	
Total	163	100

Table 6 Pain at review (Series II)

	No	Per cent
Without pain	23	77
Intermittent mild pain	5	16
Intermittent moderate pain	2	7
	30	100

Although these secondary procedures gave relief, treatment with Moore's endo prosthesis was regarded as unsuccessful Many patients were already bedridden or confined to a wheel-chair owing to other disabilities before the fracture In these, function of the hip was regarded as good provided the joint was mobile and did not interfere with the care of the patient and provided the pre fracture level of function was regained The overall results are given in Table 5 No late complications occurred

Series II Of these 30 patients, 23 denied pain in the hip and seven complained of occasional postfunctional pain or pain on weightbearing (Table 6) All are old age pensioners, but many are still physically active (Table 7)

Table 7 Activities (Series II)

	No
Heavy work	1
Household	22
Can manage daily activities	5
Hospital care	2
	30

Table 8 Activities of daily living (Series II)

	Yes	With some difficulty	No
Staircase	20	8	2
Stocking and shoes	23	5	2

The ability to climb a staircase and to put on stockings and shoes is shown in Table 8 Nine patients used no walking stick, 13 used one stick largely on the surgeon's recommendation, and eight needed two sticks

Of the 163 patients 133 died during the follow-up period, death taking place 1 to 9 years (average 3 4 years) after operation Figure 1 shows the expected duration of survival according to Swedish population statistics compared with the figures for these patients The likelihood of an earlier death after fracture of the neck of femur is significantly increased ($P < 0\ 001$ and $< 0\ 05$ 2 and 4 years after operation)

DISCUSSION

In these elderly patients, many in poor general condition (Alffram 1964), several factors contribute to the unfavourable prognosis of fractures of the femoral neck The blood supply to the femoral head is very often reduced by atherosclerosis (Müssbichler 1970) Furthermore, the blood supply is reduced owing to the trauma (Müssbichler 1970) Preoperative investigations to assess the blood supply and consequently the prognosis have not been very rewarding (Hulth 1956, Johansson 1964, Mussbichler 1970) In many patients the femoral neck and head are osteoporotic and brittle The head may therefore be dam-

Table 1 Frequency of complications following nailing of femoral neck fractures

Author		Pseudarthrosis + necrosis of the femoral head Per cent
Linton	1944	52
Spotoft	1944	54
Carlquist	1947	45
Odén	1947	40
Ibsen	1951	55
Slungaard et al	1962	45

sand and Östersund All have been examined at regular intervals for an average period of 3.4 years after operation and the findings are shown in Table 2

Series II comprises 30 patients from the above series still alive and examined by the author In this series the average interval between operation and clinical review was 3.5 years

The indications for treatment of recent fracture of the femoral neck with Moore's prosthesis were as follows *Age above 70 years mental* illness blindness or rheumatic or other disabling conditions (Table 3) The anaesthetic time is also shown and compared with the anaesthetic time in reposition and nailing at the same hospitals Moore's southern approach was used the femoral neck being divided at an appropriate angle 1 cm above the lesser trochanter to avoid any leg length discrepancy The operation differed from Moore's (1959) technique in one respect viz the capsule and the lateral rotators were sutured

To start with the patients were kept in bed for a week after operation Later however as *more experience was gained they got up the day* after the operation and appropriate physiotherapy including walking exercises was given They were discharged from hospital as soon as they could manage activities of daily living—on average 4 weeks after operation (range 2–11 weeks)

Table 2 163 patients with femoral neck fractures treated by primary Moore arthroplasty

Age (years)	mean	78
	range	66–95
Sex	women	133
	men	30
Side	right	68
	left	95
Follow up time (years)	mean	3.4
	range	2–9
Duration of anaesthesia * (minutes)	mean	96
	range	45–195

* For nailed patients 25–145 minutes Mean 63

Table 3 Indications for Moore prosthesis

	No
Debilitating diseases	25
Poor reduction	27
Old fractures	7
Age above 70	104
Total	163

RESULTS

Series I Postoperative complications are shown in Table 4 The postoperative mortality includes all those who died within 6 weeks of the operation Other complications are subdivided into those producing and those not producing late sequelae Among the former, it was necessary to remove the prosthesis in seven patients A total arthroplasty (McKee Farrar) was performed in one patient

Table 4 Postoperative complications (Primary series 163 cases)

		No	Per cent
Mortality (6 weeks postoperatively)		15	9
Cardiac	7		
Pulmonary	5		
Cerebral	3		
Without late disability		17	10.4
Fracture during operation	6		
Thromboembolism	2		
Haematoma	7		
Wound rupture	2		
With late disability		8	5.4
Luxation	2 *		
Deep infection	5 *		
Unexplained pain	1 †		

* Salvage procedure Girdlestone
† Salvage procedure McKee Farrar

operated upon for inguinal hernia or gall stones also have a shorter expectation of life (Dahlin 1973) independent of the immediate postoperative mortality

The total anaesthetic time may be taken as a rough measure of the surgical trauma It is found (Table 2) that for nailing the anaesthetic time is two-thirds of that for arthroplasty The difference is barely significant, and could be further reduced for arthroplasty In arthroplasty it is possible to induce anaesthesia on the operating table, and the patient can even be aroused there, whereas in nailing anaesthesia must cover the time taken to place the patient on the traction table and be continued until he is back again in bed The surgical magnitude of arthroplasty compared to nailing is also indicated by the fact that the postoperative mortality is the same (Froysaker 1968) as are other postoperative complications such as infection pneumonia etc (Banks 1962 Lunceford 1965 Froysaker 1968 Riska 1971)

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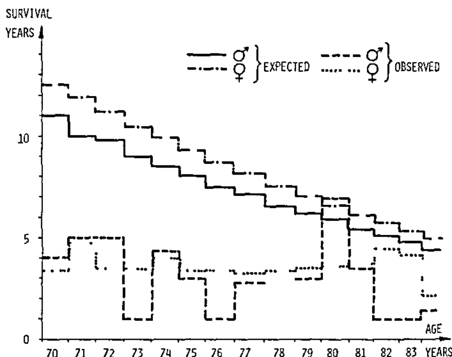


Figure 1 Expected and observed duration of survival

aged by the trauma or by nailing (Bohler 1953). Sometimes the head is more or less an empty shell and very difficult to fix irrespective of the type or number of nails or screws because the tips of the fixing device have no grip inside the head. Also, several different means of fixation have given the same poor results (Table 1). Slipping of the nails is common, and the fixation of the nails by means of a plate to the lateral part of the femoral cortex often leads to penetration and destruction of the acetabulum by the nails (Barnes 1967) when resorption occurs in the fracture line and shortening of the neck takes place. The subtended angle of the fracture line can also create shear forces, making it difficult to maintain exact reduction (Pauwels 1935, Scheck 1965). In subcapital fractures the primary reduction is sometimes also difficult.

The result of nailing can be a long convalescence, limited mobility, and dependence on other people, or, alternatively, the care of an otherwise handicapped patient may be made still more difficult increasing the burden on hospital services. As Thorén (1975) points out, only 25 per cent of the patients were able to walk after nailing, and the burden on hospital staff increased in two-thirds of the patients. The present investigation shows that all patients regained their pre-fractural level of function. Furthermore, a second operation, such as arthroplasty, after failure of nailing may be risky, especially in an elderly patient. The usefulness of reposition and nailing of femoral-neck fractures in elderly patients is therefore open to question, and primary arthroplasty is recommended instead (Coventry 1959, Lunceford 1965, Riska 1971).

In young, otherwise healthy patients the femoral head ought not to be replaced by a prosthesis. It is not known where to set the age limit, because we do not yet know how long a prosthesis will continue to function without pain, but it could probably be set lower than in the present series. In this investigation patients had a shorter expectation of survival compared with the general population (Swedish Life Table). The reduction is probably not due to the arthroplasty *per se*, since aged patients treated by nailing (Froysaker 1968) and aged patients

operated upon for inguinal hernia or gallstones also have a shorter expectation of life (Dahlin 1973) independent of the immediate postoperative mortality

The total anaesthetic time may be taken as a rough measure of the surgical trauma It is found (Table 2) that for nailing the anaesthetic time is two-thirds of that for arthroplasty The difference is barely significant, and could be further reduced for arthroplasty In arthroplasty it is possible to induce anaesthesia on the operating table, and the patient can even be aroused there, whereas in nailing anaesthesia must cover the time taken to place the patient on the traction table and be continued until he is back again in bed The surgical magnitude of arthroplasty compared to nailing is also indicated by the fact that the postoperative mortality is the same (Froysaker 1968) as are other postoperative complications such as infection, pneumonia etc (Banks 1962 Lunceford 1965 Froysaker 1968 Riska 1971)

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Acta orthop scand 47, 214-216 1976

SURGICAL EXPOSURE OF THE LESSER TROCHANTER AND THE MEDIAL PROXIMAL PART OF THE FEMUR

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An exposure of the medial proximal femur between the femoral artery and vein medially and the femoral nerve laterally is described As far as the authors know, this exposure has not been described in the literature before In their opinion it is to be preferred to the exposures already published when lesions of the medial proximal part of the femur are to be treated Moreover, the exposure can be extended distally as described by Henry (1970)

Key words surgical approach, lesser trochanter proximal femur

Accepted 16 xi 75

Exposure of the medial proximal part of the femur, i e the region of the lesser trochanter and that part of the femur distal to this, is not easy because of the presence of blood vessels and veins medioventrally and of the thick muscle layer medially and mediodorsally

We therefore use a new method of exposure As far as we know, it has not been previously described in the literature

TECHNIQUE OF OPERATION

The patient lies with his hip in flexion abduction and external rotation This position is assisted by a cushion under the contralateral half of the pelvis The incision runs from the middle of the groin longitudinally lateral to the blood vessels (Figure 1)

The M sartorius is prepared from the medial side and is retracted laterally This exposes the femoral vessels and nerve At this level nearly all the branches of the femoral nerve run laterally, providing the innervation of the musculature at the front of the thigh One of the most medial branches is the saphenous nerve which passes through the adductor canal together with the femoral artery and vein The branches of the femoral nerve are prepared and retracted laterally It is not necessary to prepare the femoral artery and the femoral vein separately These can be left in the sheath which facilitates re exploration should this be necessary (Figure 2) The M vastus medialis and the tendon of the M iliopsoas are now further prepared In this process some blood vessels from the femoral vein and the femoral artery to the M vastus medialis have to be cut This does not give rise to problems as there is ample collateral circulation in this region The descending branch of the lateral circumflex femoral artery is situated proximally in the wound (Figure 3) The M vastus medialis can now be stripped from proximal to distal, exposing the medial part of the femur (Figure 4)

CASE REPORTS

So far five operations have been performed on four patients (one male and three female) by this method in all cases for an osteoid osteoma of the medial proximal femur

In two cases the diagnosis of osteoid osteoma



Figure 1 Position of the limb Flexion abduction and external rotation in the hip joint A cushion is placed under the contralateral buttock

Figures 1-4 Exposure of the lesser trochanter and the medial proximal part of the femur through an anteromedial approach

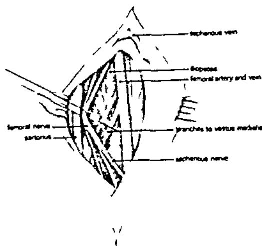


Figure 2 After opening the superficial fascia Dissection of the femoral artery and vein mediodorsally and the femoral nerve and sartorius ventrolaterally

was confirmed by the pathological examination In one patient, a 5 year old girl, the resection performed initially was inadequate The diagnosis of osteoid osteoma could not be confirmed by pathological examination A recurrence of the complaints was found with this patient The osteoid osteoma was removed in the second operation which was performed without problems by the same route The removal of the osteoma was confirmed by pathological examination The other patient in whom the diagnosis of osteoid osteoma could not be confirmed by pathological examination is free of complaints The minimum follow-up period is 3 years

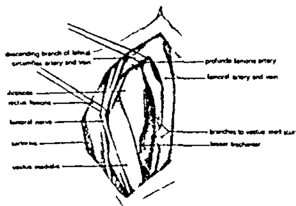


Figure 3 After cleavage of the vessels to the vastus medialis By further dissection the lesser trochanter and iliopsoas come into view

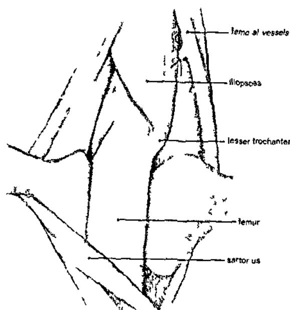


Figure 4. After stripping the vastus medialis. Medial aspect of the proximal femur is widely exposed.

DISCUSSION

Various exposures of the proximal femur giving access to the region of the lesser trochanter have been described in the literature. Henry (1970) gives an anterolateral approach, which also permits exposure of the medial femur. Banks & Laufman (1953) describe a posterior exposure of the femur. Ludloff (quoted in Campbell's Operative Orthopaedics) describes a medial exposure through the adductor muscles. Nicola (1966) describes a dorsal exposure of the lesser trochanter. These techniques give either limited exposure of the medial proximal part of the femur, or an exposure of the dorsal or ventral femur with poor visibility of the medial part.

The technique described by the authors has the following advantages when used in lesions of the lesser trochanter and *medial proximal part of the femur*: Approach through a relatively thin muscle layer and good visibility of both lesser trochanter and medial proximal femur. This method can be combined with the medial distal exposure according to Henry (1970), giving exposure of the whole medial part of the femur.

ACKNOWLEDGEMENT

The authors wish to thank Miss H. F. Spijker for the illustrations.

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Acta orthop scand 47 217 225 1976

DYSPLASIA EPIPHYSEALIS HEMIMELICA

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Four typical cases of dysplasia epiphysealis hemimelica are reported the age when first examined varying from 18 months to 5 years The observation periods varied from 3 20 years After fusion between the accessory ossification centres of the osteochondroma and the regular epiphysis no further enlargement was observed In three cases an enlarged medial femoral condyle was resected in two cases the resection was done through bone leaving a non-cartilaginous surface in the knee joint This procedure seems to have no harmful consequences one of the patients seen 19 years later had no complaints and the knee joint appeared almost normal on X rays

Key words epiphysis osteochondroma exostosis *child growth*

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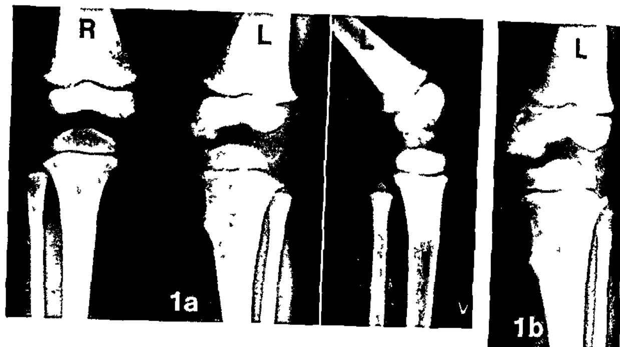
Dysplasia epiphysealis hemimelica is a growth disorder of unknown aetiology The characteristic pathological finding is an overgrowth of the cartilaginous cells on one side of the affected limb resulting in formation of an osteochondroma The medial side is affected more often than the lateral The talus the distal femoral and the distal tibial epiphyses are most frequently involved (Theodorou & Iantis 1968)

The disorder was first described by Mouchet & Belot (1926) using the term *Tarsomégalie* Fairbank (1956) reported 14 cases from orthopaedic centres in England and introduced the name dysplasia epiphysealis hemimelica He presumed that endogenous or exogenous agents affect the limb buds of the foetus for a very short time in a minute area The clinical manifestation may vary depending on the area affected and possibly also on the time at which the agents act

To date about 60 cases of this disorder have been reported (Barta et al 1973) The purpose of the present paper is to add four typical cases (one having an observation period of nineteen years following surgery) and to stress some aspects of importance concerning treatment of this rare disorder

CASE REPORTS

Case 1 A girl 3 years old when first seen at the hospital because of increasing valgus deformity of the left knee She had no other complaints A bony prominence on the medial femoral condyle was found but no limitation of movement of the knee joint X rays (Figure 1 a) showed an enlargement of the medial femoral condyle with centres of ossification separated from the regular ossification of the epiphysis Further the X rays showed an irregularity in the outline of the medial side of the proximal tibial



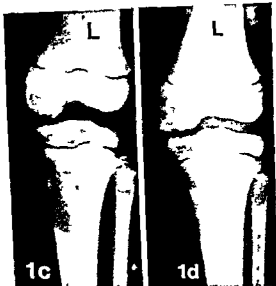
epiphysis, and an exostosis on the medial side of the proximal metaphysis. During an observation period of 1 year, the deformity increased and the separated ossification centres fused with the regular ossification centres of the epiphysis (Figure 1 b). Arthrotomy was done and the bony prominence of the femoral condyle was removed, leaving a bony joint surface in the knee. Histopathological examination showed normal cartilage and bone.

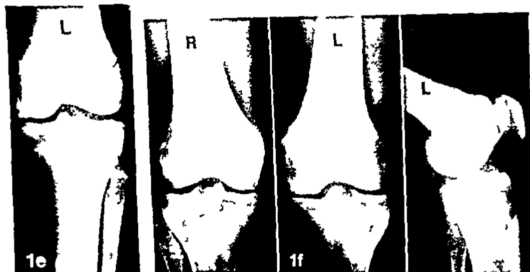
Two months after operation the patient had a normal range of movement in the knee joint and no complaints. X-rays 1 year after operation (Figure 1 c) showed that the irregular ossification centres had been only partly removed. On the medial side of the tibial epiphysis a new separate ossification centre was also seen. At the age of 8 (Figure 1 d), the irregular ossification centre of the tibia had fused with the epiphysis. The exostosis of the metaphysis had not increased in size. At the age of 13 (Figure 1 e) the joint surfaces of the tibia as well as the femur were almost normal. An increased breadth of the tibial metaphysis was observed at the place where the exostosis had been previously. At 23 years of age she had no complaints regarding the knee joint, X-rays showed some flattening of the joint surface of the medial condyle but were otherwise normal (Figure 1 f). The lower limb involved was 2 cm longer than the other. The same observation had been made when she was 13.

Case 2. A boy, 2 years old when first seen at the hospital. He had had periods of limping on the left leg and a locking phenomenon of the knee joint. A slight valgus deformity of the knee was found, but the range of movement was normal. X-rays (Figure 2 a) showed a separate centre of ossification near the medial femoral condyle. One year later X-rays showed multiple separated ossification centres and further enlargement of the medial femoral condyle (Figure 2 b). The enlargement was removed by resection through the cartilage separating the epiphysis from the irregular ossification centres. The femoral condyle could therefore be left covered with cartilage. A corpus liberum found in the knee joint was the reason for the locking phenomenon. It consisted of hyalin cartilage covering an ossification centre and had probably become separated from the femoral condyle. The histopathological examination of the removed enlargement showed normal cartilage and bone structure. Two months after operation the patient had no complaints and the knee function was normal. At 12 years of age the patient had no problems with his knee joint and the X-rays were entirely normal (Figure 2 c).

Case 3. A boy, 5 years old, was first seen because of pain in the right knee. He presented with a slight valgus deformity of the knee and ankle. X-rays (Figure 3 a) showed an enlargement of the medial femoral condyle with ossification centres almost totally fused with the epiphysis. Separated ossification centres were also seen around the talus, navicular and first cuneiform, some fused with the bone (Figure 3 b). Operative correction was not found necessary. At the age of 8 he had no complaints and the knee joint movement was normal. No increase in the valgus deformity or enlargement of the femoral condyle had occurred. On the contrary the out

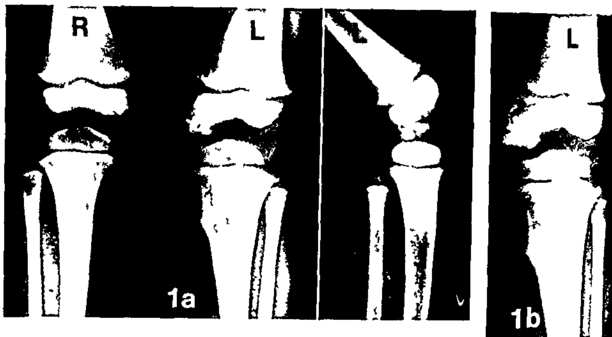
Figure 1 Case 1 a) X rays of the knee joints of a girl 3 years of age Separated ossification centres are seen at the left medial femoral epiphysis An exostosis is present in the tibial metaphysis b) The osteochondroma was fused to the epiphysis at 4 years c) The knee at 5 years 1 year after resection of the femoral condyle A new irregular ossification centre is seen at the medial tibial epiphysis The X rays of the left knee at 8 (d) at 13 (e) and at 23 years (f) show a spontaneous development towards an almost normal joint





growth was fully fused with the epiphysis and seemed relatively small because of the increase in the size of the epiphysis The shape of the condyle was more normal (Figure 3c) There was likewise no worsening in the ankle region

Case 4 A boy who had been treated since the age of 18 months because of a valgus deformity of the left knee He had no complaints X rays (Figure 4a) showed enlargement of the medial femoral condyle with multiple centres of ossification and on the tibial side an exostosis was seen on the proximal tibial metaphysis At 5 years of age the patient was first referred to hospital because of a marked valgus deformity of the knee The affected limb was 2 cm longer than the other He also had a swelling of the medial malleolus X rays (Figure 4b) showed that the irregular ossification centres of the femur had fused with each other and also with the ossification centre of the epiphysis The exostosis of the tibial metaphysis was seen only as an increased breadth of the proximal metaphysis X rays of the ankle region (Figure 4c) showed separate centres of ossification in the medial malleolus At operation the cartilage covering the enlarged femoral condyle was found to be very thin and bluish The prominence of the femoral condyle was resected leaving a raw bony surface in the joint No cartilaginous space was found between the ir



epiphysis and an exostosis on the medial side of the proximal metaphysis. During an observation period of 1 year the deformity increased and the separated ossification centres fused with the regular ossification centres of the epiphysis (Figure 1 b). Arthrotomy was done and the bony prominence of the femoral condyle was removed, leaving a bony joint surface in the knee. Histopathological examination showed normal cartilage and bone.

Two months after operation the patient had a normal range of movement in the knee joint and no complaints. X-rays 1 year after operation (Figure 1 c) showed that the irregular ossification centres had been only partly removed. On the medial side of the tibial epiphysis a new separate ossification centre was also seen. At the age of 8 (Figure 1 d) the irregular ossification centre of the tibia had fused with the epiphysis. The exostosis of the metaphysis had not increased in size. At the age of 13 (Figure 1 e) the joint surfaces of the tibia as well as the femur were almost normal. An increased breadth of the tibial metaphysis was observed at the place where the exostosis had been previously. At 23 years of age she had no complaints regarding the knee joint. X-rays showed some flattening of the joint surface of the medial condyle but were otherwise normal (Figure 1 f). The lower limb involved was 2 cm longer than the other. The same observation had been made when she was 13.

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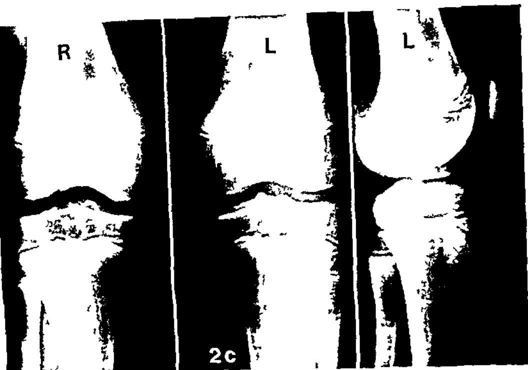


Figure 2 Case 2 a) X rays of the knee joints of a boy at the age of 2 years showing separate ossification centres near the medial femoral epiphysis b) Pre operative X rays at 3 years c) Normal joints at 1?

regular ossification centres and the epiphysis. Hi t pathological examination showed normal bone and cartilage One year after operation the boy had no complaints regarding the knee or the ankle joint

DISCUSSION

Four cases of dysplasia epiphysealis hemimelica have been treated at the Sophies Minde Orthopaedic Hospital The age when first observed medically varied from 18 months to 5 years Three of the patients were male and one female In two cases the left and in two cases the right lower limbs were affected in all cases on the medial side The medial femoral condyle was affected in all cases In one case this was the only localisation The upper tibial condyle the lower tibial epiphysis the talus the navicular and the medial cuneiform were each affected in one instance The distribution according to sex side and affected epiphysis is in agreement with other publications (D Angio et al 1955 Theodorou & Lantis 1968)

Two of the cases reported here also had metaphyseal affection in both instances as an exostosis of the tibia metaphysis well separated from the epiphysis This must be interpreted as a true metaphyseal abnormality and not as a secondary manifestation as stated by Kettelkamp et al (1966) After some years the metaphyseal exostosis in our cases was seen only as an increased breadth of the metaphysis (Cases 1 and 4) Metaphyseal affection has earlier been reported by several authors (Ingelrans & Lacheretz 1953 Fairbank 1956 Mosely 1957 Saxton & Wilkinson 1964 Trevor 1950) This metaphyseal affection to date observed in 11 typical cases seems to be a part of the growth disorder The term "epiph

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Histopathological examination showed in all cases an osteochondroma with groups of proliferating normal cartilaginous cells and centres of ossification. This is in agreement with the findings of other authors (Donaldson et al. 1953, Rechnagel 1960, Barta et al. 1973).

The four cases reported here have been followed up for from 3 to 20 years. In the femoral condyle the separated ossification centres fused with the regular epiphysis in two cases at an age of 3-4 years. In one case first seen at the age of 5 years the fusion had already taken place. The enlargement of the femoral condyle increased in this period before fusion (Cases 1, 2 and 3). In two cases there was no further enlargement of the condyle after fusion, in fact some normalisation was seen (Cases 1 and 3). A similar course was also found with regard to the tibial epiphyseal affection and the tibial metaphyseal exostosis. This observation is of importance with regard to treatment of this growth disorder. An explanation for this course could be found in the observation of Barta et al. (1973). They described an almost normal growth cartilage between the epiphysis and the separated ossification centres. Probably most of the growth of the enlargement takes place in this growth plate, accordingly after fusion the osteochondroma does not increase in size to any appreciable extent.

Surgery was found necessary in three cases, all because of an increased valgus deformity in the knee joint. Arthrotomy was done and the enlarged medial femoral condyle was resected. In one case the operation was done at the age of three before fusion leaving a cartilage covered surface in the joint. In two cases the operation was done after fusion leaving a bony surface in the knee joint. One of these patients was reexamined 19

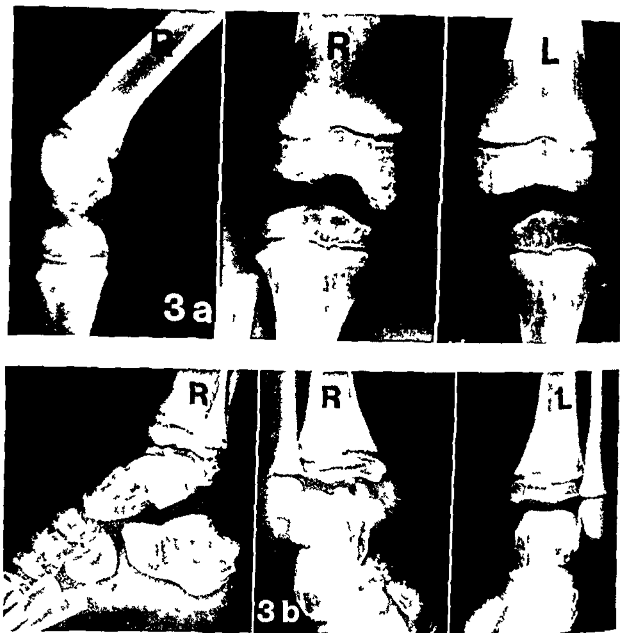


Figure 3. Case 3. a) X-rays of the knee joints of a boy at the age of 5 showing an enlargement of the right medial femoral condyle. b) X-rays of the ankle and foot of the same patient showing multiple centres of ossification around the talus, navicular and first cuneiform. c) X-rays at the age of 8 show some spontaneous improvement of the knee affection.

yseal used in describing this condition is therefore not strictly correct. In two of our cases the affected limb was found to be longer than the unaffected one. This finding has also been reported by others (D'Angio et al. 1955, Rechnagel 1960, Saxton & Wilkinson 1964) and probably reflects an increased growth rate of the whole limb.

The initial complaints were deformity of the joint, limping, pain and in one patient a locking phenomenon in the knee joint caused by a corpus liberum. In all cases a valgus deformity of the knee was found. One patient had a valgus deformity in the ankle joint caused by affection of the medial malleolus. Another only had an enlargement on the inside of the ankle, caused by affection of the talus.



Histopathological examination showed in all cases, an osteochondroma with groups of proliferating normal cartilaginous cells and centres of ossification. This is in agreement with the findings of other authors (Donaldson et al 1953, Rechnagel 1960, Barta et al 1973).

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Surgery was found necessary in three cases, all because of an increased valgus deformity in the knee joint. Arthrotomy was done and the enlarged medial femoral condyle was resected. In one case the operation was done at the age of three, before fusion, leaving a cartilage-covered surface in the joint. In two cases the operation was done after fusion, leaving a bony surface in the knee joint. One of these patients was reexamined 19

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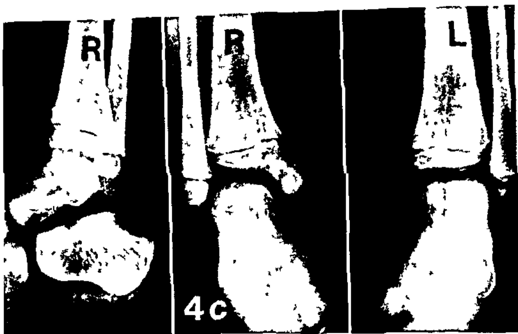


Figure 4 Case 4 a) X rays of the knee of a boy at the age of 18 months showing enlargement and separated ossification centres in the medial femoral condyle and an exostosis of the tibial metaphysis b) Preoperative X rays at the age of 5 years show a bony tumour fused with the epiphysis c) X rays of the ankle at the same age show eccentric ossification centres in the medial malleolus

years later She had no complaints On clinical examination the knee joint was normal and X rays did not reveal any obvious pathological findings However, if surgery is necessary in the knee region the optimum time is probably before fusion between the accessory ossification centres and the rest of the epiphysis i e before 4 years of age Resection through cartilage is then possible

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4a

R R L

4b

Figure 1 The stages of the experiment

this day of postnatal life the upper physeal plate of the femur divides into two distinct parts one for the head and one for the trochanter

The statistical analysis (paired and simple t tests) is based on 100 pairs. The right femur from the pair had its trochanter ("T" femur) or its head ("H" femur) resected the left bone of the pair was left intact ("I" femur) being the intra-experimental control for the operated counterpart. An additional in vivo control group was examined five rats on each predetermined day were sacrificed and the lengths of the femurs were measured. The growth of the *in vivo* femurs was thus noted during the 16 days of the experiment starting on the ninth postnatal day

The growth inhibiting effect of Alizarin Red S was examined (Harris et al 1964 1968). On the eighth postnatal day i.e., 24 hours before their sacrifice the young rats were injected intraperitoneally with Alizarin Red S 0.01 mg/g weight

RESULTS

Growth in length

Figure 2 compares the growth increment (Δl) of the whole femur in diffu-

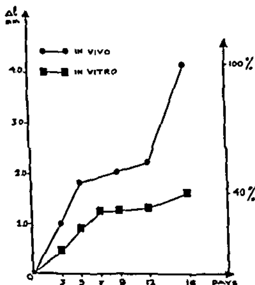


Figure 2 Growth increment (Δl) of the whole "I" femurs in diffusion chamber—in vitro—compared to whole intact femurs—in vivo

Acta orthop scand 47, 226–230, 1976

GROWTH OF THE RAT FEMUR IN DIFFUSION CHAMBERS

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Growth in the length of 9 day old rat femurs, isolated and cultivated in diffusion chambers was studied for a limited period of 16 days An increment of 40 per cent of the *in vivo* length was observed It could be established that the elongation was due to chondral growth of which 40 per cent occurred at the proximal and 60 per cent at the distal end of the bone during the 16 days of observation When the trochanteric or the head epiphyses with their physeal plates were resected no statistically significant loss in total length occurred A small but statistically highly significant biphasic growth due to enchondral ossification was found Resection of the trochanter produced a widening of the cervico diaphyseal angle (valgisation) of an average of 11 2° The findings in this series of isolated femurs are—in a general way—similar to those observed in the living animal

Key words rat femur, growth, diffusion chambers

Accepted 8 vii 75

Various experiments have been conducted in order to understand the mechanisms which govern the activity of the epiphyses situated at the ends of bones (Morgan & Sommerville 1962, Khermosh et al 1972, Weissman 1974) In these studies, whole animals have been used in *in vivo* experiments However, it was thought that by depriving the femur of muscle traction neural stimulation and blood circulation —i e, by isolating the femur—some more insight into the basic processes involved could be gained Thus the type of experiment using diffusion chambers, as described below, was developed

METHODS AND MATERIALS

The experimental set up is depicted in Figure 1 Nine day old rat femurs were dissected free of soft tissue under sterile conditions utilizing microsurgical techniques care being taken not to damage the periosteum The prepared bone shafts were pierced through at their middle by 5/0 stainless steel wire to serve as a marker The bones and their various segments were measured with a micrometer fitted to a standard microscope The bones were placed in the pre sterilized diffusion chambers which were implanted into the peritoneal cavity of adult male rats The filter utilized on the diffusion chambers had pores of 0 22 μ diameter

The host rats were sacrificed on pre determined days The diffusion chambers were removed the bones were extracted and their various segments were again measured using the method described above

Nine day old rats were selected because on

MICRO DISSECTION

9 DAYS OLD

ADULT MALE

± 0.1 mm

DIFFUSION CHAMBER

Figure 1 The stages of the experiment

this day of postnatal life the upper physeal plate of the femur divides into two distinct parts one for the head and one for the trochanter

The statistical analysis (paired and simple t tests) is based on 100 pairs The right femur from the pair had its trochanter ("T" femur) or its head ("H" femur) resected the left bone of the pair was left intact ("I" femur) being the intra-experimental control for the operated counterpart An additional *in vivo* control group was examined five rats on each predetermined day were sacrificed and the lengths of the femurs were measured The growth of the *in vivo* femurs was thus noted during the 16 days of the experiment starting on the ninth postnatal day

The growth inhibiting effect of Alizarin Red S was examined (Harris et al 1964 1968) On the eighth postnatal day i.e., 24 hours before their sacrifice the young rats were injected intraperitoneally with Alizarin Red S 0.01 mg g weight

RESULTS

Growth in length

Figure 2 compares the growth increment (Δl) of the whole femur in diffu

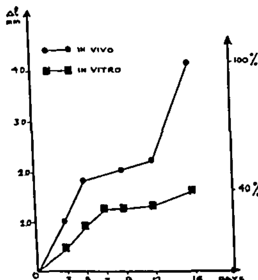
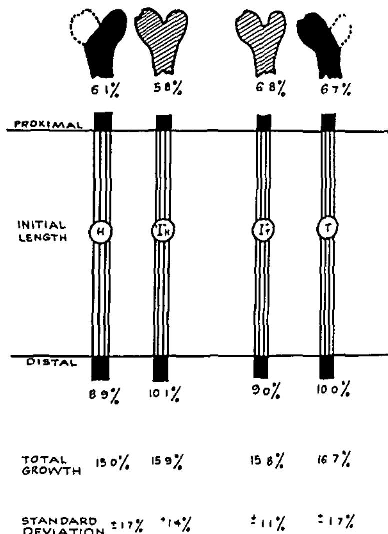


Figure 2 Growth increment (Δl) of the whole "I" femurs in diffusion chamber—in vitro—compared to whole intact femurs—in vivo

Figure 3 Growth increment of femurs, in percentage, incubated for 16 days in diffusion chambers



sion chambers under *in vitro* conditions compared with whole femurs grown *in vivo* during the 16 days of the experiment It shows that whereas the *in vivo* femurs grew 4 1 mm (100 per cent) during the 16 days of the experiment, the *in vitro* femurs grew only 1 6 mm (40 per cent) during the same period

The graphs in Figure 2 show that there is a great similarity between the two curves, with an initial rise, a plateau and then again an acceleration of growth These changes in the growth rates are statistically significant to $P<0\ 001$ (Paired t-test), conforming with other observations on the saltatory nature of biological growth (Swinson 1974) Sixty per cent of the total $\triangle l$ (growth increment) occurred at the distal end and 40 per cent of the total $\triangle l$ at the proximal end of the femur The same proportion was present in the "T" femurs as well as in the "H" femurs, by the end of 16 days of growth

Figure 3 summarizes the results in paired femurs The initial length of the bones was extrapolated to a standard length and the total and differential growth ratios were calculated as percentages The two columns to the left pertain to "H" femurs (head resected) and to their intact controls ("I_H" femurs) The two columns to the right belong to the intact controls ("I_T" femurs) and the trochanter resected femurs ("T" femurs) It appears that there was a small difference between the control femurs "I_T" and "I_H" There is no statistically

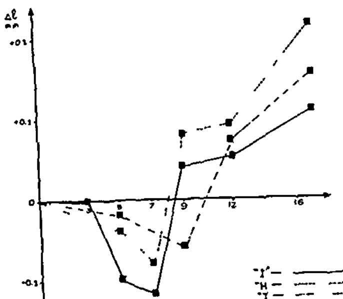


Figure 4 The biphasic growth increment (Δ l) of the ossified portion of the bone in femurs cultivated in diffusion chambers ($P<0.005$)

significant difference in the total length between the "H" femurs and their controls although a diminished distal and an enhanced proximal lengthening can be noted. The trochanter resected "T" femurs which grew more than their controls also grew more than the "H" femurs. Most of the overgrowth occurred at the distal end; however the difference is not statistically significant.

Figure 4 shows graphically the elongation of the ossified portion of the bone. Although the measured lengths were small the differences were statistically highly significant ($P<0.005$ with paired t test). During the initial 7 days there is a diminishing in length—negative phase of elongation or a lag period which is followed by a definite increase which rises steeply with time in a similar pattern for all three types of bones but which differs significantly in amount.

Neck shaft angle

During the experiment we noticed that the "T" femurs showed a persistent and measurable valgisation—i.e. an opening of the cervico-diaphyseal angle as compared with their control "I" femurs. An indirect method of measurement which compared 18 such pairs was applied. All of the "T" femurs showed c.d.a. widening with a minimum of 3° in one and a maximum of 27°, with a mean of 11.2°±6°.

Growth inhibiting effect of Alizarin Red S

The bones exposed to Alizarin Red S only grew approximately half their initial expected length during the 16 days of the experiment.

DISCUSSION

It was established that the lengthening of the bones was by real growth and not by swelling as suggested by Fell & Mellanby (1958) and Biggers (1963). This statement is substantiated by the following:

1. The pH, P_{O_2} and P_{CO_2} values of the fluid in the diffusion chambers were similar to the hosts' arterial blood with the pH slightly to the acid side.
2. The *in vitro* growth curve as shown in Figure 2 is similar to the *in vivo* one, the difference being only in the rate

and ultimate length—due probably to unfavourable conditions in the experimental environment

3 The Alizarin Red-S, which is a known growth inhibitor, caused a 50 per cent decrease in the total lengthening of the bones exposed to it

4 The soft tissue overgrowth from the areas of muscle insertions showed that there was a favourable environment for cell proliferation in the diffusion chamber

5 The observed clubbing (enlargement of the epiphyseal cartilages, more than elongation and apposition of the shaft) was similar to the observations of Pratt (1959) in the postnatal changes of rat femurs *in vivo* He stated that the clubbing is part of this phase of postnatal development and is due mainly to epiphyseal cell proliferation by mitosis and partly to cell enlargement

The length contribution of the proximal and distal ends of the femur to total length is quite similar to that found by Khermosh et al (1972) in living rabbits during the entire growth period of the young animals An analogous difference was found by Andersen et al (1963) in humans, by following the rate of departure of Harris' lines of growth arrest in children from the physeal growth plates The similarity of our findings to the *in vivo* developments in different species may suggest that the genetical information predetermining the bone length has a very deep penetration

Resection of the trochanter or of the head did not produce any (statistically significant) shortening at the end of the observation period Thus, isolated femurs behave similarly to those in living animals studied by Weissman (1974) However, the isolated femurs did not show a statistically significant enhanced growth of the distal end as did the living animals, even if this end grew more The relatively short period of observation (16 days in all) may account for this discrepancy

The widening of the cervico-diaphyseal angle seen in the trochanter resected femurs is similar to that observed in humans and in experimental animals (Ewald & Hirohashi 1973) Whether it is due to the dynamics of growth, turgor pressure unopposed by other cells damaged by the resection, or due to genetically inherent information in the cells left intact cannot be answered yet

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Acta orthop scand 47 231 235 1976

SYNOVIAL SARCOMA A CASE REPORT

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The case described of a 40 year-old woman with a 26 year history of a chronic non specific knee disorder is a rather typical example of synovial sarcoma according to the information given by other authors over the past three to four decades The diagnostic difficulties and failures are clearly illustrated It must be emphasized that severe obscure joint symptoms such as our patient presented over the many years before death should have led to a proper surgical exploration of the knee Furthermore it should be unnecessary to stress the importance of performing a histological examination whenever excising abnormal tissue

Key words sarcoma synovia knee

Accepted 20 xi 75

Synovial sarcoma is a rare tumor The symptoms are non specific and may develop insidiously over many years There are often diagnostic problems and commonly the tumor has reached a stage beyond radical cure before the true nature of the disease is revealed (Haagensen & Stout 1944 Tillotson et al 1951 Ackerman & del Regato 1970)

We report a case which clearly demonstrates these typical features

CASE REPORT

M R a 40 year-old woman who had sustained at the age of 14 a distortion injury to her right knee No distinct lesion was detected, but she developed a chronic painful condition with limited extension ability from which she suffered until the final diagnosis was made 26 years later

Five years after the injury a small X ray visible flat calcified tumor was excised from the popliteal fossa. It was *not examined histologically* Two years later another tumor was excised from the scar line but again no *microscopy* was performed

Eighteen years of relapsing knee disorder *followed* Some improvement was achieved by *physiotherapy* and various drugs (salicylates antiflogistics hydrocortisone etc) *also gave her* some short periods with improved function and *relief Finally* the knee became *very painful and* almost completely stiff in 40° of flexion and an arthrodesis was performed The knee films showed no distinct articular changes (*Figure 1*) Bony union was achieved (Figure 2 A B) and the patient was able to walk without pain after 3 *months Six* months after this operation however the knee became swollen red and painful and the patient was admitted to our hospital for the first time

The temperature was elevated to 38° C, SR 40 mm WBC 8000 mm³ and knee films revealed *pathological* changes interpreted as signs of chronic osteitis (*Figure 3 A B*) An exploratory incision revealed no *pus however* and a biopsy showed fibrous tissue with calcifications and some *signs of chronic* inflammation Antibiotics

Figure 1 Lateral roentgenogram of the right knee No specific articular changes can be detected



seemed to improve the situation but after 2 weeks the symptoms recurred and a new X ray examination now displayed the true, malignant nature of the disease with numerous spherical translucent lesions in the knee region (Figure 4) and also the indisputable spread to both lung fields (Figure 5) Furthermore a group of enlarged firm nodules were detected in the right groin and a biopsy from this region showed a tumor tissue with dense sheets of malignant spindle cells and areas with more epitheloid like cuboidal cells often lining slit like clefts (Figure 6 A B) A diagnosis of synovial sarcoma was made A mid thigh amputation was performed (Figure 7) and microscopic examination showed details as described above The patient was given methylaminopterine (Methotrexate 'Lederly) combined with local radiation of the groin and the mediastinum Gradually however pulmonary insufficiency and cachexy developed and the patient died some 6½ months after the amputation

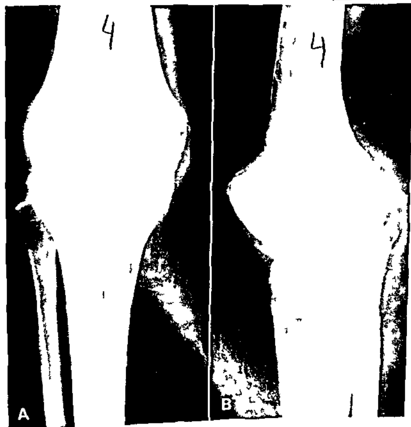


Figure 2 A B Roentgenogram showing a solid bony union between the condylar parts 3 months after arthrodesis ad modum Charnley The lateral projection (B) reveals traces of the removed steel rods in the metaphyseal regions of tibia and femur otherwise no pathological changes are visible

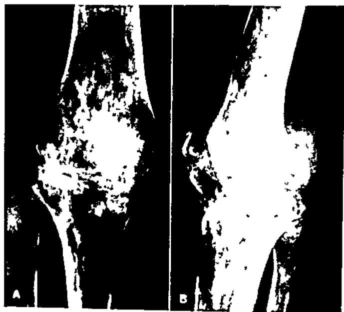


Figure 3 A B Roentgenogram showing marked general osteoporosis, and in addition some irregular, small, translucent areas in the lateral condylar part The changes were considered to represent a chronic osteitis



Figure 4 A frontal planigram revealing multiple spherical translucent spots throughout the condylar areas interpreted as a massive tumor infiltration

DISCUSSION

A history of trauma is often present in cases of synovial sarcoma, but any real etiological connection between trauma and the tumor formation has never been proved (Ackerman & del Regato 1970) We cannot prove the existence of synovial sarcoma in our patient at the first operation more than 20 years before death, but the localization in the popliteal fossa is common, and similar long-lasting case histories have been reported previously (Haagensen & Stout 1944, Tillotson et al. 1951, Cadman et al 1965)

Our case clearly demonstrates the nonspecific joint symptoms making the diagnosis difficult and leading to repeated, misleading surgical explorations (Haagensen & Stout 1944, Tillotson et al 1951, MacKenzie 1966)

The tendency to recurrence after local excision is well known, and the tumor sooner or later spreads to the lungs and also frequently to the regional lymph nodes (Haagensen & Stout 1944, Ackerman & del Regato 1970) In our patient



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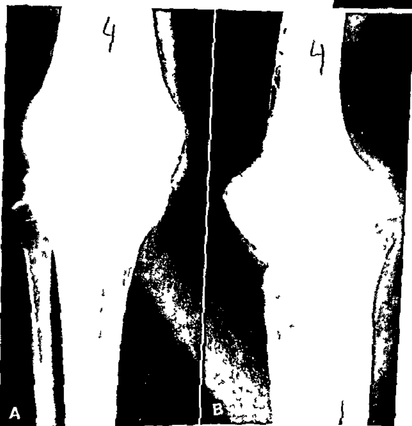


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Figure 5 Frontal chest roentgenogram, showing multiple, 'snow ball'-like shadows scattered all over both lung fields



Figure 6 A Synovial sarcoma in a 40 year-old woman There are groups of polyhedral and spheroidal as well as spindle-cells lying in a fibrous stroma (Hematoxylin and eosin × 89)

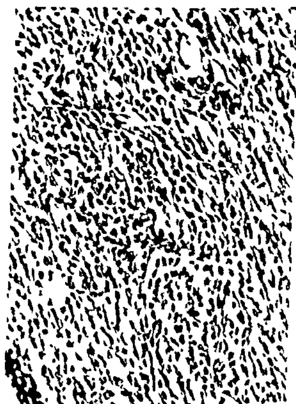


Figure 6 B Higher magnification of area of tumor shown in Figure 6 A The tissue is cellular with small clefts lined by cuboidal cells simulating epithelial lining cells (Hematoxylin and eosin × 223)



Figure The macroscopic appearance of a frontal section posterior view of the right knee specimen after mid thigh amputation There is a massive infiltration of sarcomatous tissue throughout most of the bony parts spreading diffusely into the adjacent soft tissue

the diagnosis was not made before wide spread dissemination was evident

In general surgery is the main treatment and the only accepted measure is high amputation where this is possible otherwise radical excision The radio-sensitivity of the tumor is disputed (Ackerman & del Regato 1970), but radiation is probably of some value both pre and postoperatively and some arrest of growth in the metastases have been observed (Haagensen & Stout 1944 Tillotson et al 1951) In our patient radiation and cytostatic drugs seemed to improve the general condition for a couple of months but no objective proof of regression could be detected

The prognosis is poor but many reports of long lasting remissions indicate a better outlook if proper, radical treatment is instituted early enough (Pack & Ariel 1950 Cadman et al 1965, Moberger et al 1968)

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Acta orthop scand 47, 236–240, 1976

THE MECHANICAL AND STRUCTURAL CHARACTERISTICS OF THE TIBIO-FIBULAR INTEROSSEOUS MEMBRANE

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The tibio fibular interosseous membrane was studied in the scanning electron microscope It is made up of two fibrous networks a major one composed of large diameter fibres aggregated into bundles and a fine filamentous network without a preferred orientation between these main fibre bundles Mechanical studies have shown that the interosseous membrane is stronger, but less extensible, parallel to the direction of the main fibre bundles which, therefore, probably have a load bearing function

Key words structure, mechanical properties, function, interosseous membrane

Accepted 16 xi 75

The main function of the tibio-fibular interosseous membrane is to hold the tibia and fibula together and when these bones are fractured it contributes to the stability of the fracture (Sarmiento et al 1974) Therefore, it obviously has a mechanical function In this study we have quantitated the tensile properties of the tissue and correlated them with the architecture as seen in the scanning electron microscope

MATERIALS

The interosseous membranes used in this study were obtained postmortem from the left leg of three males They were cleaned of adhering tissue and attached muscle and cut from the edge of the tibia and fibula to produce a sheet approximately 15 cm long and 1 cm wide Segments of the tissue which were to be examined in the scanning electron microscope were cut into squares approximately 0 5 × 0 5 cm and fixed in formal saline pH 7 The tissue specimens for mechanical testing were cut in two directions (a) parallel to the main fibre bundles and (b) at right angles to them

METHODS

Mechanical studies

Strips approximately 2 mm wide and 20 mm long were cut weighed and mounted in a specially designed testing fixture (Minns et al 1973) using Eastmans 910 adhesive They were clamped and immersed in isotonic saline and the tests were conducted at room temperature on a table model tensile testing Instron type TM1112 The strips were extended at a constant extension rate of 0 2/minute to complete rupture

The ultimate tensile stress was calculated from the maximum load recorded divided by the initial cross sectional area of the specimen whereas the strain at rupture was determined from the recorded extension at maximum load divided by the initial rest length expressed as a percentage Strips that slipped at the grips (indicated by non linear movement of the chart pen recorder associated with the extensometer) were eliminated from the results and only strips



Figure 1. Scanning electron micrograph of the main fibre bundles observed in the interosseous membrane (× [illegible]00)

that ruptured between the grips were used in this study

Scanning electron microscopy

The specimens for scanning electron microscopy were cut in various planes and prepared by the method of Finlay et al (1971). The samples were examined in a Cambridge Stereoscan S4 electron microscope operating at 20 kV and were photographed with an Exacta VX 2500 camera on Ilford FP4 120 film.

RESULTS AND DISCUSSION

Mechanical properties of the interosseous membrane

Table 1 is a summary of the results of the stress strain characteristics of the interosseous membrane determined in 20 specimens parallel and perpendicular to the main fibre bundle axis. In the direction of the main fibre bundles the tissue



Figure 2 Scanning electron micrograph of a cross section of the membrane showing the corrugation of fibre sheets which form the bundles at different layers (× 520)

is 15 times stronger than perpendicular to these fibres but is much less (1/5) extensible This result is in keeping with previous studies on load bearing collagenous tissues For example Bullough et al (1970) showed that the ultimate tensile strength of meniscal tissue is dependent upon the axis of loading, the tensile strength of the menisci in the direction of the principal fibre bundles was 4 to 10 times that of the strength perpendicular to the fibres

Scanning electron microscopy

Naked eye examination is sufficient to show that the major fibre bundles of the interosseous membrane join the tibia and fibula at an angle of between 20 and 30° to the vertical, running distally from the



Figure 3 Scanning electron micrograph of the surface of a corrugated fibre sheet showing fibrils passing at right angles to the main fibre bundle direction (× 16,200)

proximal end of the tibia to the fibula In the scanning electron microscope these main fibre bundles can be seen to consist of large fibres with a diameter ranging between 30 and 40 microns aligned parallel to the long axis of the bundle (Figure 1) Each bundle appears to contain approximately 50 of these fibres some of them bifurcate and others are continuous In some areas the fibres have a rather laminated structure and although the direction of the fibrils within these fibres is fairly uniform the overall direction changes from layer to layer (Figure 2) There is also a second fibrous network consisting of fine fibres with a diameter range of 0 5 to 1 micron (Figure 3) arranged as a continuous mesh

All of these structural factors contribute to, and explain the observed mechanical behaviour of the tibio-fibular interosseous membrane It has been



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Acta orthop scand 47 241 249 1976

THE EFFECTS OF RIGIDITY OF INTERNAL FIXATION PLATES ON LONG BONE REMODELING

A Biomechanical and Quantitative Histological Study

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The effect of rigidity of internal fixation plates on long bone remodeling was studied using two types of plates with considerable differences in stiffness The plated bones were subjected to bioengineering quantitative histological and cortical thickness studies after 9 and 12 months The biomechanical results together with the quantitative *histological* measurements of the macroscopic architecture showed that tissue characteristics of the plated bones were similar However, because of the larger cortical area the less rigidly plated femora can sustain significantly higher loads and energy before failure Cortical thickness measurements also showed that rigid plate immobilization results in thinning of the cortex of the underlying bone The experimental results suggest that cortical bone remodels according to functional stress demands and the osteoporosis secondary to rigid plate protection is consequent to thinning of its cortex

Key words internal fixation plates stiffness osteoporosis cortical thinning biomechanical properties quantitative histology

Accepted 6 1 76

This investigation is a continuation of our study to determine whether the osteopenia caused by protection from stress in plated bones can be reduced by the use of less rigid fixation devices (Woo et al 1976 Akeson et al 1975) A less rigid fixation plate requires the plated bone to carry more of its normal physiological stress, and thus induces remodeling to stronger bone following Wolff s law (Cochran 1969, Perren et al 1969, Hutzschenreuter et al 1969, Chamay & Tschantz 1972) The benefits of this type of fixation are that a shorter period of external protection should be required to reach acceptable bone strength for unprotected activity once the plate is surgically removed It remains to be shown whether comparable union rates can be achieved with plates of reduced stiffness

Previous experiments by this labora

The authors wish to express appreciation for financial support from NIH Grant AM 15478 and a research grant from San Diego Veterans Administration Hospital to conduct this research

Table 1 The results of the mechanical tests that were conducted on interosseous membrane The results show the mean and standard error of the Ultimate Tensile Stress and strain at rupture of 20 specimens tested in the two directions indicated

	Ultimate Tensile Stress (Kg_f/cm^2)	Strain at rupture (%)
Parallel to main fibre bundle	920 ± 205	7 7 ± 2 1
Perpendicular to main fibre bundle	41 ± 13	40 5 ± 7 1

shown (Minns 1975) that, on the surface of the tibial shaft, the load during walking is not carried uniformly throughout the bone but that there is an area of high tensile stress corresponding to the tibial insertion of the interosseous membrane Kimura (1974) loaded the tibia and fibula to correspond to the walking posture and with the interosseous membrane cut, the tensile strain on the posterior side of the mid-shaft increased Our results show the way in which the structure of the interosseous membrane correlates with its load bearing function It should be remembered, however, that this membrane also plays an important role in stabilizing both transverse and spiral fractures of the tibia and the structure described helps resist any displacement at the fracture site (Sarmiento et al 1974)

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AL, AM, PM and PL, representing anterior lateral anterior medial, posterior medial and posterior lateral segments respectively (Figure 2) These bone specimens were submerged in a 37° C saline filled tank and subjected to 4 point bending test to failure The bioengineering test procedure was described in detail in a previous publication (Woo et al 1976) Bioengineering tests were not done on the remaining four larger segments i e anterior medial posterior and lateral segments (shown in Figure 2), because of the irregular curved geometry These larger segments together with the four smaller (3 0 mm wide strips) segments were analyzed by quantitative histological procedures, however Eight pairs of normal canine femora were also cut and subjected to 4 point bending tests under identical testing conditions The results of the normal canine femora were compared with the experimental femora

Quantitative histological methods

The eight segments of each femur were aligned in a parallel sequence fixed in absolute alcohol infiltrated with methacrylate monomer under vacuum embedded in a mold and cured under UV light When the plastic was sufficiently hardened the block was trimmed and 120 μ sections were cut serially using a milling bone saw equipped with a diamond edged 12½ cm diameter saw blade The width of the saw blade was 500 μ. Very slow cutting speeds and continuous water cooling were used to minimize fragmentation The serial sections were ground down to approximately 70 μ thick using wet and dry sandpaper with absolute alcohol as a lubricant Finally the sections were polished by hand to 50 μ thick with ground glass plates After washing with several changes of alcohol, sections were cleaned in xylene and mounted conventionally

Each of the sections was scanned by a rectilinear grid eye piece at 80 × magnification as described by Harris & Weinberg (1972) This is

...ount counted in cluded unlabeled cortical bone tetracycline labeled cortical bone and porosity

Cortical thicknesses of all eight segments of the femur were also measured optically using a graduated magnifying glass (7 ×) accurate to 0 1 mm The thickness of each segment was measured at three places i e at the midpoint and at both ends All measurements were made by two independent observers and the mean values were calculated

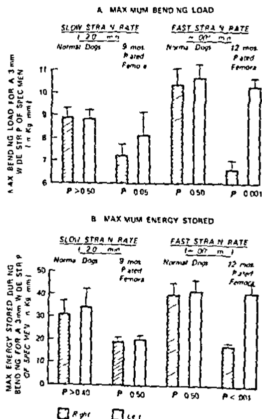


Figure 3 Histograms showing the differences in maximum bending load and maximum energy stored in the Vitallium (right) and GFMM (left) plated femora Since there were no significant left and right differences in the normal femora, the significant differences in the experimental femora are concluded as results of plate fixation P values given underneath the bars are for differences between right and left sides

RESULTS

The GFMM plated femora were not remarkably different in gross appearance from the vitallium plated femora A few carbon particles were evident in adjacent tissues near the screw hole sites where the screw hole tap had abraded the plate during surgery on the GFMM side The overlying capsule appeared inert, with no evidence of accumulation of serous exudate The histological appearance of the membrane was essentially as previously reported for a short-term study of

tory utilized two internal fixation plates with significant differences in bending and axial stiffness for fixation of mid-shaft osteotomies of the canine radius. Clinical and biomechanical evaluations of the healed bones at 4 months post-operatively showed the rate of healing and the strength characteristics to be similar (Woo et al. 1974). Quantitative histological evaluation of these bones revealed lower cortical porosity and more new bone formation in the less rigid plated side (Akeson et al. 1975). The investigation presents a second experimental model using the intact canine femur to study the effect of rigidity of fixation plates on long-term bone remodeling.

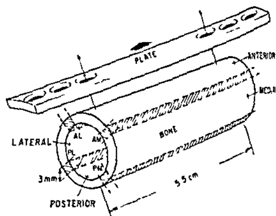


Figure 2. A schematic diagram showing the system of identification used for the eight segments subdivided from the mid-diaphysis of the canine femur. Note that the plate was applied on the anterior (A) surface of the bone

MATERIALS AND METHODS

The materials selected for this study were graphite fiber methylmethacrylate resin composite (GFMM) and conventional vitallium. The difference in moduli of elasticity for GFMM ($1-4 \times 10^5$ kg/cm²) and vitallium (26×10^5 kg/cm²) is approximately an order of magnitude (Woo et al. 1974). Hence, a GFMM plate of similar geometrical design as a vitallium plate would have a bending and axial stiffness one-tenth that of the vitallium plate. The plates used were of identical dimensions and configurations. They were 9 cm long and had six screw holes. Both plates had identical sized screw holes and countersinks. The location of screw holes was also the same (Figure 1).

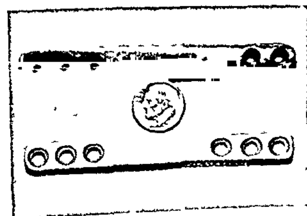


Figure 1. Photograph of the GFMM and Vitallium plates used for the canine femora

Animal studies

Six adult mongrel dogs with an average weight of approximately 20 kg were used as experimental animals. After confirming skeletal maturity by x-ray, the right and left femora of each animal were plated on the anterior surface with a vitallium and a GFMM plate, respectively. A skin incision centered over the lateral thigh was used to expose the femur. The periosteum was then stripped from the bone anteriorly and the plate was positioned on the shaft. Screw holes were drilled using a centering drill guide and the holes were tapped. Three screws were used at each end to fasten the plate onto the bone. The wound was then irrigated with sterile saline and closed routinely. The animal was redraped and the contralateral femur was plated in an identical procedure.

Three of the animals were maintained for 9 months, and three were maintained for 12 months post surgery. The animals remained in individual cages for 4 weeks and were then sent to an animal farm where they were allowed freedom to exercise. Routine x-rays were made at monthly intervals. Starting 16 weeks prior to sacrifice the animals were given 750 mg daily of oxytetracycline (Terramycin) for 8 weeks and dimethylchloretetracycline (Declomycin) 450 mg daily for the remaining 8 weeks for quantitative histological studies.

Specimen preparation and bioengineering tests

The animals were sacrificed with Euthanasia and the femora were harvested. The mid-diaphysis of the femoral specimen was cut to obtain four longitudinal test strips, 3.0 mm wide and 5.5 cm long. The four strips were labeled

Table 1 A comparison of cortical thickness and total counts of segments of bone from the left and right femoral diaphysis Note that consistent statistical differences were obtained for the corresponding thickness and total count data

	A		AM		M		PM		P		PL		I		AI	
	L*	R*	L	R	L	R	L	R	L	R	L	R	L	R	L	R
9 month series																
Cortical thickness (in mm)																
Mean	2 2	1 9	2 3	2 0	2 4	2 0	2 2	2 2	2 1	2 2	2 4	2 2	2 4	2 0	2 2	2 1
Std Err	0 1	0 1	0 1	0 1	0 2	0 1	0 1	0 1	0 1	0 1	0 1	0 1	0 1	0 1	0 2	0 1
t test	$P < 001$		$P < 001$		$P < 005$						$P < 050$		$P < 005$		$P < 050$	
Total counts																
Mean	400	192	154	125	332	221	145	138	246	268	152	134	278	232	153	121
Std Err	39	36	6	21	17	19	13	16	44	24	18	11	29	39	33	17
t test	$P < 001$		$P < 001$		$P < 001$						$P < 025$		$P < 025$		$P < 050$	
12 month series																
Cortical thickness (in mm)																
Mean	2 1	1 7	2 5	1 8	2 2	1 7	2 2	1 9	2 3	1 8	2 3	1 9	2 0	1 8	2 1	1 9
Std Err	0 1	0 1	0 2	0 1	0 1	0 1	0	0 1	0 1	0	0	0	0 1	0 1	0 1	0 1
t test	$P < 001$		$P < 005$		$P < 001$		$P < 010$		$P < 010$		$P < 001$		$P < 010$			
Total counts																
Mean	259	230	144	112	294	230	144	119	232	185	145	120	237	204	119	120
Std Err	9	25	13	7	29	54	5	6	17	22	9	4	17	13	19	15
t test	$P < 005$		$P < 001$		$P < 005$		$P < 001$		$P < 001$		$P < 001$		$P < 001$			

* L = Left femur (GFMM plated)
* R = Right femur (Vitallium plated)

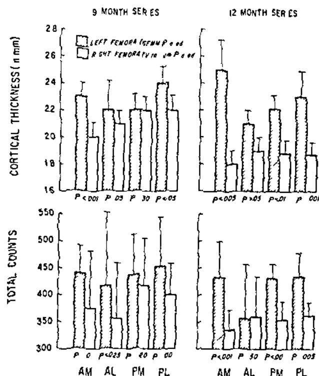


Figure 4 This histogram shows cortical thickness and total counts (cortical area) of 3 mm wide bone strips from homotypic segments of the plated left and right femoral diaphyses Note that only those segments where the cortical areas are different also showed simultaneous differences in cortical thickness

fracture healing using GFMM plates (Akeson et al 1975)

The bioengineering data and methods of computation were presented in detail in an earlier communication (Woo et al 1976) The test results of the mechanical properties (bone as a material) of the AL, AM, PM, and PL segments of the femora showed no significant difference in the ultimate bending strength (σ_f) and the flexural modulus of elasticity (E) between the less rigid, GFMM plated femora and the more rigid, vitallium plated femora Also, σ_f and E for the anterior (AM and AL) segments were similar to those of posterior (PM and PL) segments for both the GFMM and vitallium plated femora In addition, essentially no significant difference in σ_f or E existed between the plated femora or the normal femora

Measurements of the structural properties of the femur (bone as an organ) i e maximum bending load and maximum energy stored, showed a significant advantage of the GFMM plated over the vitallium plated femora The GFMM plated femora sustained a larger maximum load and absorbed more energy before failure than the vitallium plated femora As the duration of plating increased from 9 to 12 months, the structural differences became more marked (Figure 3) The difference in maximum bending load increased from 12 5 per cent to 55 per cent and the difference in maximum energy absorbed increased from no significant difference at 9 months to more than a factor of two at 12 months

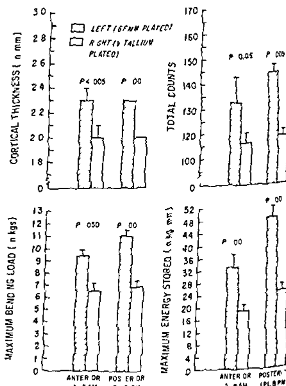


Figure 5 A comparison of anterior (AL & AM) and posterior (PL & PM) segments of 12 month plated femoral diaphyses Consistent statistical differences were found in cortical thickness quantitative histological data and bioengineering test results between left (GFMM plated) and right (Vitallium plated) specimens

Table 3 *Quantitative histological data from the homotypic segments of bone from the left and right femoral diaphysis The difference between left and right homotypic segments was compared statistically using Student's t test on all categories of quantitative histological studies Significant differences are indicated by appropriate P values All data are presented in percentage of total cortical bone area*

	A		AM		M		PM		P		PL		L		AL	
	L*	R*	L	R	L	R	L	R	L	R	L	R	L	R	L	R
9 month series																
Unlabeled bone																
Mean	77 8	84 9	81 9	85 1	88 1	93 0	91 7	93 9	87 2	92 2	87 5	93 0	84 8	93 8	84 4	88 8
Std Err	8 0	3 3	5 1	5 5	4 8	2 3	3 3	1 8	4 8	1 3	3 9	1 5	5 1	1 8	7 1	4 6
Labeled bone																
Mean	9 6	7 7	9 9	5 3	6 3	3 7	5 2	2 2	8 0	4 4	9 2	2 7	10 5	3 0	8 7	3 7
Std Err	3 3	2 6	3 6	2 3	3 8	1 3	2 8	0 8	4 3	0 9	3 5	0 6	4 9	0 8	4 5	1 8
Porosity																
Mean	10 8	5 3	5 1	1 4	2 9	2 5	1 7	1 5	2 0	1 4	2 1	1 6	*2 7	1 6	5 2	1 2
Std Err	5 8	3 4	2 3	0 5	1 5	1 8	0 9	0 8	1 0	0 6	1 0	0 5	1 8	1 3	2 9	0 6
12 month series																
Unlabeled bone																
Mean	88 0	94 7	85 0	94 4	92 6	96 3	90 0	96 8	89 0	94 0	86 7	95 1	89 6	93 5	90 4	92 6
Std Err	5 1	2 2	5 0	1 4	2 7	0 6	2 8	0 9	5 3	1 8	4 3	1 5	4 3	2 3	2 8	5 2
Labeled bone																
Mean	5 7	2 2	8 4	2 9	2 6	1 3	6 9	1 0	5 3	3 0	6 8	2 3	6 4	2 9	6 4	5 2
Std Err	3 1	1 7	2 8	0 9	1 2	0.8	2 3	0 5	2 5	1 3	3 9	1 2	2 6	1 6	2 1	4 8
Porosity																
Mean	4 0	1 2	5 3	0 8	1 8	0 5	3 1	0 3	2 8	1 8	4 6	1 1	3 3	1 7	1 7	1 0
Std Err	2 1	0 6	2 1	0 6	1 3	0 3	1 1	0 2	1 7	1 2	1 8	0 9	1 7	1 2	0 8	0 3
							$P < 0\ 05$				$P < 0\ 05$					

* L = Left femur (GFMM plated)
* R = Right femur (Vitallium plated)

Table 2 A comparison of the thickness of posterior and anterior cortices of GFMM and Vitallium plated femora This comparison shows that the thickness of the posterior cortex of the vitallium plated femur was significantly greater than that of the anterior cortex, i e osteoporosis occurred beneath the plate No such difference in cortical thickness was observed for the GFMM plated femur

	AL,A,AM	PM,P,PL
1) 9 month series		
a) Left (GFMM plated)	2 3±0 3	2 3±0 4
	($P > 0\ 50$)	
b) Right (VIT plated)	2 0±0 4	2 3±0 2
	($P < 005$)	
2) 12 month series		
a) Left (GFMM plated)	2 2±0 4	2 3±0 2
	($P > 0\ 50$)	
b) Right (VIT plated)	1 7±0 3	1 9±0 1
	($P < 0\ 05$)	

Cortical thickness results

The cortical thickness of the corresponding left and right segments (homotypic areas) were compared The cortical thickness of the GFMM plated femora was consistently greater than the vitallium plated femora (Figure 4 and Table 1) The thickness data from PM, P, and PL segments were pooled and termed the posterior side and compared statistically with the pooled AM, A, and AL segments termed the anterior side For the vitallium plated femur, the posterior cortical thickness was significantly greater than the anterior side for both the 9 and 12 month series ($P < 0\ 005$ and $P < 0\ 05$, respectively), whereas on the GFMM side there was no anterior-posterior cortical thickness difference for either series (Table 2)

Quantitative histological results

Random grid area counting was performed on seven serial cross-sectional slides obtained from the midshaft of each femoral diaphysis The detailed data are presented in Table 3 There was no significant left and right difference in percentage of unlabeled bone, labeled bone or porosity for either the 9 or 12 month series with the exception of PM and PL in the 12 month series, which showed significant porosity differences Unlabeled bone ranged from 78 to 97 per cent of the cortical area, whereas the tetracycline labeled bone and porosity each ranged from a minimum of 1 per cent to a maximum of 11 per cent of the cortical area A comparison of any one segment of bone with the remaining seven segments in the same femur also showed no consistent difference in percentage of unlabeled bone, labeled bone or porosity

However, a comparison of the total counts of the segments from the homotypic left and right femora revealed a significantly larger number of counts on the GFMM side in most of the segments (Table 1) In addition, only those segments where the total counts were significantly different also showed significant difference in cortical thickness (Figure 4) These results confirmed the validity of the statistical counting method used because the total counts should be proportional to the area of bone That is since the width of all the segments was 3 mm (AM, PM, PL, and AL segments were cut to this width), the cortical thickness should directly correspond to the total counts as the results have demonstrated

DISCUSSION

Two plates with considerable differences in bending stiffness were applied on the anterior surface of opposite canine femoral diaphyses for 9 and 12 months duration to study the effect on long bone remodeling The bioengineering evaluation of the femoral specimens showed no significant difference in mechanical properties as represented by the maximum bending strength (σ_t) and the elas-

opportunity will exist to achieve optimization of design and material selection for skeletal implants once the response of bone to implants of varying stiffness is understood in detail Only then can the trade-offs between the need for rigid fixation in early repair and less rigid fixation for later remodeling be understood and the lessons applied effectively

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Correspondence to Wayne H Akeson M D Professor and Head Division of Orthopedic Surgery M-004 University of California San Diego La Jolla California 92093 U.S.A

tic flexural modulus of bone (E) between the vitallium (rigid) plated and GFMM (less rigid) plated femora The mechanical properties of the plated femora were also similar to the normal canine femora The *quantitative histological evaluation* of the same segments of the bone were consistent with the biomechanical data No significant difference in *percentage* of unlabeled old bone, tetracycline labeled new bone, or cortical porosity existed between the femora immobilized by these different plates The values for cortical porosity obtained in the plated bone were in the range of those of the normal canine long bones reported by Harris & Weinberg (1972), and Enneking et al (1972) The above observations suggest that the macroscopic architecture of bone, and hence its resulting mechanical properties, remained un*changed in spite of plate immobilization*

Gross architectural differences, however, were seen Thinning of the cortical wall due to medullary canal enlargement was noted This occurred to a greater degree on the rigid plated side The 4-point bending test results showed that the GFMM plated femora have superior structural properties to the vitallium plated femora Since the mechanical properties *of the bones are the same, the* greater structural strength in the GFMM plated side should be a result of increase *in bone mass* Again, this biomechanical observation was corroborated by the histological measurements (total counts) and by the cortical thickness measurements, where consistent results were found (Figure 5)

The logical conclusion of this investigation based on *the quantitative histological* and biomechanical measurements would be that rigid plate immobilization of long bone results in osteopenia because of reduction in normal bone stress However, such stress protection does not seem to alter the substance of bone, yet the net amount of cortical bone is significantly reduced, probably as a result of increased resorption on the endosteal surface

The present quantitative histological results are not to be confused with the osteotomized or experimental fractured model that was presented earlier (Akeson et al 1975) In the earlier model the *cortical porosity values were significant*ly higher (7 per cent for GFMM plated radius, and 14 per cent for stainless steel plated radius) With an identical tetracycline labeling period (16 weeks) the present models have only 1 to 11 per cent of new bone formation as represented by the tetracycline labeled bone These values were much lower than the labeled bone area of stainless steel plated (23 to 28 per cent) and GFMM plated (35 to 49 per cent) osteotomy sites of the radial diaphyses In the osteotomized model, of *course, accelerated bone formation* and resorption were seen as a result of repair However, potential advantages of a less rigid internal fixation plate for long-term skeletal fracture fixation were suggested in the experiment just concluded Long term studies of fracture healing which give information on effects of plates of varying bending stiffness on the remodeling phase of fracture repair will be re*quired to be certain that this observation* is valid

The present study also opens the possibility of using other potential surgical materials as less rigid internal fixation plates In addition to the GFMM material we are investigating a plate made of titanium alloy (Ti 6A1–4V) (Bardos 1974), designed to have a bending stiffness ten times less than a conventional *stainless steel plate These plates* are being used in an osteotomized canine femur model and studies up to 18 months are in progress A considerable amount of work remains to be done to evaluate the implications of material properties and design of implants on bone histology and architechture An

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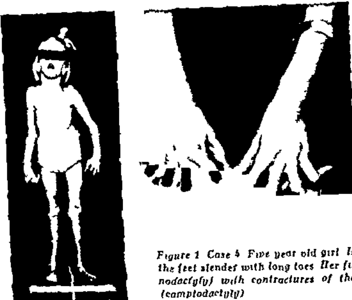


Figure 1 Case 5 Five year old girl Her extremities are long and thin the feet slender with long toes Her fingers are long and thin (arachnodactyly) with contractures of the proximal interphalangeal joints (camptodactyly)

No ocular or cardiovascular abnormalities were found Investigation of his family revealed that the patient s two brothers were normal but his mother and uncle were both affected and are described below His grandfather had finger contractures and a moderate deformity of the spine

Case 2 R S (born 6 October 1939) the mother of T S was seen at the hospital at the age of 35 years In her childhood she had contractures of both elbows She now had long extremities and long slender fingers and toes Slight contractures of the proximal interphalangeal (PIP) joints were present on both hands but otherwise joint movement was normal. She had a moderate scoliosis of the thoracic spine and very distinctive antihelices of her ears

Case 3 K G (born 31 July 1938), R.S s brother had been examined at the hospital at the age of 18 years because of low back pain A follow up examination was carried out at the age of 37 years His extremities were long and thin with long fingers and toes A flexion contracture of 15° of the PIP joints of the fingers was detected Moreover there was a flexion contracture of 10° in the left elbow and 15° in the right Examination of the spine revealed a slight left sided scoliosis in the lumbar region The patient stated that the contractures of the elbows and fingers had been more marked when he was young

Case 4 W B (born 27 February 1970) was seen in the pediatric department when 5 days old She was treated in an incubator because of breathing difficulties Her weight at birth was 3000 grams She had extraordinarily long fingers and toes and contractures of the knees (40°), elbows and fingers Both thumbs were lying across the palm of the hand The feet were deformed the right in the equinovarus and the left in the calcaneovalgus position Examination of the hips showed reduced abduction but no contractures The condition was diagnosed as arthrogryposis The foot deformities were treated with repeated plaster casts and the contractures by cautious passive stretching During the following months the contractures diminished but a kyphoscoliosis developed. At the age of 4 years the patient was supplied with a Milwaukee brace On re examination at age five the hip knee and elbow movements were normal The



Figure 2 Case 4 The ears are deformed with flattened helix and crumpled antihelix

Acta orthop scand 47, 250-253, 1976

CONGENITAL CONTRACTURAL ARACHNODACTYLY

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Five cases of congenital contractural arachnodactyly (CCA) are reported Three belong to the one family CCA has often been mistaken for Marfan's disease and arthrogryposis multiplex Because CCA has a more favourable prognosis, it is very important to be able to recognize this syndrome

Key words congenital contractural arachnodactyly, Marfan's syndrome, arthrogryposis multiplex congenita, connective tissue disorder, joint contractures

Accepted 11 i 76

Congenital contractural arachnodactyly (CCA) is a dominantly inherited disorder of the connective tissue A few years ago the syndrome was separated from Marfan's disease and delineated as a pathological entity (Epstein et al 1968, Beals & Hecht 1971) The most characteristic features are arachnodactyly, multiple congenital contractures, dolichostenomelia (long, thin limbs), deformed external ears and kyphoscoliosis In CCA there is no lens displacement, and usually no cardiac involvement Because the prognosis is generally favourable, it is important to distinguish this syndrome from both Marfan's disease and arthrogryposis multiplex congenita

The purpose of the present paper is to call attention to the syndrome by reporting some cases treated at our hospital

CASE REPORTS

Case 1 T S (born 21 January, 1962) He was the product of a normal pregnancy and delivery and was referred to our hospital at the age of 4 weeks because of congenital contractures of the knees, shoulders and elbows He had noticeably long, thin fingers and toes and a talipes calcaneovalgus deformity of the feet The condition was thought to be arthrogryposis multiplex The foot deformity was treated by plaster casts and braces No treatment was given for the joint contractures At the age of 21 months the contractures of the elbows, shoulders and knees had lessened, but he still walked with a flexion deformity of 15° in both knees, and a slight kyphoscoliosis was noticed At the age of 7 years he had marked arachnodactyly, and his feet were long and slender He had only slight contractures of the knees and elbows, but the kyphoscoliosis had increased The condition was now diagnosed as Marfan's syndrome, although there was no sign of cardiovascular or ocular abnormities

When re examined at the age of 13 years he was a tall boy, height 189 cm with long extremities His head had an oval shape A mild retrognathia was present, and the antihelices of both ears were somewhat crumpled The range of movement in the shoulder was normal, but there was a 10° contracture of both elbows Pronation/supination of the forearm was normal He had arachnodactyly, but no finger contractures His feet were abnormally long with long slender toes and a slight talipes calcaneovalgus was present A marked kyphoscoliosis had developed in the thoracic region

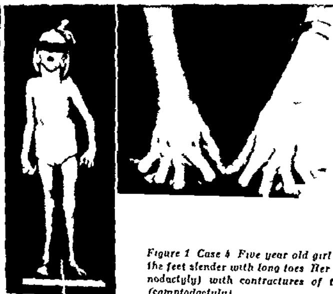


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No ocular or cardiovascular abnormalities were found Investigation of his family revealed that the patient's two brothers were normal but his mother and uncle were both affected and are described below His grandfather had finger contractures and a moderate deformity of the spine

Case 2 R S (born 6 October 1939) the mother of T.S was seen at the hospital at the age of 35 years In her childhood she had contractures of both elbows She now had long extremities and long, slender fingers and toes Slight contractures of the proximal interphalangeal (PIP) joints were present on both hands but otherwise joint movement was normal She had a moderate scoliosis of the thoracic spine and very distinctive antihelices of her ears

Case 3 K G (born 31 July 1938) R S's brother had been examined at the hospital at the age of 18 years because of low back pain A follow up examination was carried out at the age of 37 years His extremities were long and thin with long fingers and toes A flexion contracture of 15° of the PIP joints of the fingers was detected Moreover there was a flexion contracture of 10° in the left elbow and 15° in the right Examination of the spine revealed a slight left sided scoliosis in the lumbar region. The patient stated that the contractures of the elbows and fingers had been more marked when he was young

Case 4 W B (born 27 February 1970) was seen in the pediatric department when 5 days old She was treated in an incubator because of breathing difficulties Her weight at birth was 3000 grams She had extraordinarily long fingers and toes and contractures of the knees (40°) elbows and fingers Both thumbs were lying across the palm of the hand The feet were deformed the right in the equinovarus and the left in the calcaneovalgus position Examination of the hips showed reduced abduction but no contractures The condition was diagnosed as arthrogryposis The foot deformities were treated with repeated plaster casts and the contractures by cautious passive stretching During the following months the contractures diminished but a kyphoscoliosis developed At the age of 4 years the patient was supplied with a Milwaukee brace On re examination at age five the hip knee and elbow movements were normal The



Figure 2 Case 4 The ears are deformed with flattened helix and crumpled antihelix

extremities were long and thin, the feet slender with long toes and there was a combination of arachnodactyly and camptodactyly (Figure 1) Her head was oval and her ears positioned lower down than normal with flattened helices and crumpled antihelices (Figure 2) She had developed a severe scoliotic double curve, 85° in the thoracic region and 62° in the lumbar region (Figure 3) No cardiovascular disorder or lens dislocation was found The family investigation revealed no similar cases Her parents, a brother and a sister were all healthy

Case 5 (born 9 April 1975) The third child of healthy and unrelated parents He was admitted to our hospital at the age of 7 weeks because of multiple joint contractures and bilateral talipes equinovarus Shortly after birth he was given the diagnosis arthrogryposis multiplex, and the foot deformities were treated by repeated plaster casts His head was oval and a slight retrognathia was present There were marked flexion contractures of both elbows, 90° on the right side and 70° on the left Supination of the forearms was slightly reduced The thumb was lying across the palm on both hands and there was a flexion contracture of about 25° in the PIP joint of the third finger He had flexion contractures of 15° in both knees and bilateral talipes equinovarus No cardiovascular or ocular abnormities could be detected Aminoacid chromatography of urine was normal During the first 5 months of life the contractures of the fingers and knees disappeared and the contractures of the elbows became somewhat reduced His mental development seems to be normal A sister, born 1972 is healthy but the parents' first child, a son born in 1971 was still born and had multiple joint contractures and talipes equinovarus No other cases of malformation in the family could be traced



Figure 3 Case 4 A severe thoraco lumbar scoliosis at the age of 5 years 85° in the thoracic region and 62° in the lumbar region

DISCUSSION

Five cases of CCA, three belonging to one family, are reported The pattern of inheritance in CCA appears to be autosomal dominant (Hecht & Beals 1972) The transmission in one of our kindreds may be in agreement with this pattern, whereas in two cases the disorder was present in one generation only In these patients the disorder may have been caused by a mutant gen

The contractures which are symmetrical, most often affect the knees, elbows, fingers and hips The fingers are long with flexion contractures in the PIP joints, and a thumb-in-hand deformity is usual Ulnar deviation of the hands and fingers is occasionally seen The feet are long and slender and often talipes equinovarus or talipes calcaneovalgus is present The toes may be bent The limbs are long with poorly developed musculature Scoliosis or kyphoscoliosis is frequently seen in CCA, this deformity is progressive in contrast to the joint contractures which frequently tend to improve with age The deformity of the ears is often marked, a flattening of the helix and a crumpled antihelix with prominent crura Although the clinical signs in CCA are usually distinctive, there may be great variations in the manifestation of the disorder (MacLeod & Fraser 1973) The youngest of our patients showed only some of the characteristic signs

Congenital contractural arachnodactyly has many features in common with Marfan's syndrome, arthrogryposis multiplex congenita, and more uncommon disorders such as homocystinuria and

Achard s syndrome Several patients who have been considered to have Marfan s syndrome or arthrogryposis probably have CCA even Marfan s original case had no abnormality of the eye or heart (Hecht & Beals 1972) The absence of lens dislocation and cardiovascular involvement usually rule out Marfan s syndrome On the other hand CCA with congenital heart disease has been reported (Lipson et al 1974) In arthrogryposis the contractures are more rigid and do not improve spontaneously In homocystinuria due to cystathionine synthesis deficiency joint contractures are rare the deformities develop after birth and mental retardation is frequent Chromatography of urine and quantitation of serum aminoacide may be desirable in these patients in order to rule out or confirm the diagnosis of homocystinuria In Achard s syndrome the fingers are slender and somewhat elongated but contractures dolichostenomelia and external ear deformities are not present

Because CCA has a more favourable prognosis and also in order that more accurate genetic counselling can be given, it is very important to differentiate this syndrome from Marfan s disease and arthrogryposis multiplex congenita

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Acta orthop scand 47 254-256, 1976

THE INFLUENCE OF FREEZING ON THE MAXIMUM TORQUE CAPACITY OF LONG BONES

An Experimental Study on Dogs

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The strength of bone has often been measured in previously frozen samples and the freezing and thawing effect on the strength properties has been considered negligible. By means of a specially constructed torsion machine and a new method for fixing the test bone into the machine, previously frozen bones have been compared to fresh controls. The previously frozen samples were significantly weaker, with an average difference of — 4.6 per cent.

Key words: freezing, thawing, maximum torque capacity, bone, experimental measurement of bone strength

Accepted 2.ii.76

In order to determine accurately the physical properties of long bones, preparation and storage effects must be kept to a minimum. Many investigators (Braden et al. 1973, Burstein et al. 1972, Engelbrecht 1970) have used previously frozen samples of bones, assuming any effect on the physical properties to be negligible. For a closer study of this assumption, we have used a new measuring apparatus to compare the maximum torque capacity of fresh bones with that of bones thawed after 48 hours of freezing.

MATERIAL

The test material consisted of 10 femora and 10 tibiae of five adult healthy male dogs (Swedish harriers, weight 14-16 kg). From each pair of bones from the same dog one was selected at random for freezing and the other was tested fresh immediately after sacrifice.

Preparation, freezing and thawing procedure

All soft tissues were removed from the test bones after sacrifice of the dogs, leaving the periosteum intact. The samples to be frozen were wrapped in gauze saturated with physiological saline solution and put into plastic bags. The preparations were immediately placed in a freezer with a constant temperature of — 40° C.

Forty-eight hours later the bones in their bags were removed from the freezer and kept in air at + 37° C. After 5 hours the bones had a temperature of about + 35° C.

Measurement of the maximum torque capacity and maximum angle of torsion

The thawed bones were tested in torsion at about + 35° C. Within 10 minutes after sacrifice the maximum torque capacity and the maximum angle of torsion of the contralateral fresh bone were measured. All bones were kept humid until the tests were completed. During testing the maximum torque capacity, all bones in this investigation were subjected to medial rotation.

The testing machine. In a previous paper we have described a specially constructed apparatus

for recording the torque of long bones as a function of torsion angle (Stromberg & Dalen 1976)

Sources of error In a previous paper (Stromberg & Dalen 1976) we have calculated the experimental error (1 S.D.) including the error due to the difference between paired bones of the same dog expressed as a percentage of the mean value of the maximum torque capacity of the paired bones as 3.1 per cent. The error was determined by the comparative measurement of maximum torque capacity in paired bones from the same individual.

Maximum torque capacity is probably dependent upon the direction of the torque. All bones in this investigation were therefore subjected to medial rotation.

RESULTS

Compared with the fresh contralateral samples, the bones that had been frozen had a significantly ($P < 0.05$) reduced maximum torque capacity (Table 1) and a significantly ($P < 0.05$) reduced maximum angle of torsion (Table 2). In all the bones tested, a spiral fracture occurred at the diaphysis without any intermediary butterfly fragment being observed.

Table 1. Maximum torque capacity of the femora and tibiae of five dogs. One of each pair of bones was frozen and the deviation for each frozen sample is expressed as a percentage of the value for the respective control. All the bones that had been frozen were weaker than the corresponding controls (mean = —4.6 per cent, S.D. = 2.3 per cent). Paired observation test $t = 5.8$, $P < 0.05$

Dog no	Bone	Maximum torque capacity (Nm) fresh	defrosted	Percentage deviation
1	femur	34.8	33.5	—3.7
1	tibia	23.2	22.6	—2.6
2	femur	30.9	30.1	—2.6
2	tibia	22.1	21.1	—4.5
3	femur	36.4	35.0	—3.8
3	tibia	25.2	24.4	—3.2
4	femur	27.7	25.0	—9.7
4	tibia	19.7	18.2	—7.6
5	femur	20.0	18.9	—5.5
5	tibia	16.3	15.8	—3.1

Table 2. Maximal angle of torsion for the femora and tibiae of five dogs. One of each pair of bones was frozen and the deviation for each frozen sample is expressed as a percentage of the value for the corresponding control. Most of the bones that had been frozen had a smaller angle of torsion than the control (mean = —6.7 per cent, S.D. = 7.5 per cent). Paired observation test $t = 2.8$, $P < 0.05$

Dog no	Bone	Maximum angle of torsion fresh	defrosted	Percentage deviation
1	femur	36.0°	33.4°	— 7.2
1	tibia	45.8°	40.1°	—12.4
2	femur	31.2°	30.0°	— 3.8
2	tibia	38.2°	37.9°	— 0.8
3	femur	43.4°	36.2°	—16.6
3	tibia	39.8°	41.8°	+ 5.0
4	femur	39.6°	36.7°	— 7.3
4	tibia	35.5°	36.0°	+ 1.4
5	femur	36.5°	30.0°	—17.8
5	tibia	41.3°	37.9°	— 8.2

DISCUSSION

Changes in humidity and postmortem changes of the organic compound in bones have a significant influence on maximum torque capacity (Sedlin & Hirsch 1966). Most investigators (Braden et al. 1973, Burstein et al. 1972, Engelbrecht 1970), in determining bone strength, have recognized these facts, but have considered the effects of freezing to be of negligible importance.

It is known that freezing and thawing have a destructive effect on the microscopic structures of tissues (Mazur 1970). This effect is caused by the formation of ice crystals. Prompt freezing in fluid nitrogen at about —195° C largely prevents the formation of ice crystals. The temperature of the preparation can be raised to about —30° C without any noticeable crystallizing occurring, but destructive crystallization will start on further warming.

Since freezing affects tissue structures in a very prominent way, it might be assumed that the mechanical properties

are also affected Sedlin & Hirsch (1966), however, found a tendency towards increased strength in bones that had been submitted to freezing, as compared with fresh bones, although this difference was not significant Engelbrecht (1970) found no influence on maximum torque capacity or maximum angle of torsion We, on the contrary, have found that the maximum torque capacity and maximum angle of torsion of bones which have been frozen decrease significantly

This discrepancy between our results and those of Sedlin & Hirsch, as well as those of Engelbrecht, is probably due to the fact that we used a more sensitive measuring procedure

Our results indicate that the mechanical properties of previously frozen bones are significantly different from those of fresh bones No conclusions regarding the maximum torque capacity of bones in the living body should therefore be drawn from measurements on bones that have been frozen, without due consideration to possible errors incurred by the freezing and thawing processes

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Acta orthop scand 47, 257-263, 1976

EXPERIMENTAL MEASUREMENT OF MAXIMUM TORQUE CAPACITY OF LONG BONES

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By means of a new method with high precision (error 3 1 per cent), the maximum torque capacity of an entire long bone from an experimental animal was measured under standardized conditions within 10 minutes after sacrifice of the animal

Key words maximum torque capacity, bone, strength properties, experimental measurement of bone strength

Accepted 2 ii 76

Different methods of fracture treatment in diaphyseal bone can be evaluated experimentally by measurement of the maximum torque capacity of treated bones (cf Sammarco et al 1971, Uhtoff & Dubuc 1971) Such studies may also be of interest with respect to different pathological conditions, such as endocrine disturbances, malnutrition and various forms of neural or muscular dysfunction

We have developed a method by which the maximum torque capacity can be measured with high precision, and so quickly after sacrifice of the test animal that post mortem changes cannot reasonably be held to affect the physical properties of the bone (cf Sedlin & Hirsch 1966, Smith & Walmsley 1959)

METHODS

Measuring equipment

By means of a specially constructed apparatus the torque is determined as a function of the angle of torsion of a test body The apparatus consists of three units

1 Torsion machine
2 Signal generator
3 Time base recorder

The torsion machine (Figure 1) is driven by a synchronous motor with 1500 synchronous revolutions per min at 50 Hz

The action of the synchronous motor is seen in Figure 2 The angular velocity is independent of the torque for all loads smaller than the maximum torque The load in our experiments never exceeded the maximum torque and thus the test body was always torqued at a constant angular velocity The moment, as a function of time, was recorded during each experiment As the angular velocity is constant during each experiment, the moment as a function of angle is easily calculated

The synchronous motor is fed by a signal generator by means of which angular velocity can be regulated in a stepless manner The output shaft drives a gear box with a transmission ratio of 300 1 The pinion is fixed on the output shaft, and the gearwheel, supported by the machine stand, is connected to one end of the test body The apparatus is so constructed that the gear engagement force does not load the test body, which is thus loaded only by the torsional moment The other end of the test body is firmly attached to the stand by means of a fixation device and transparent acrylic tube The angular velocity of the torsion machine can be varied

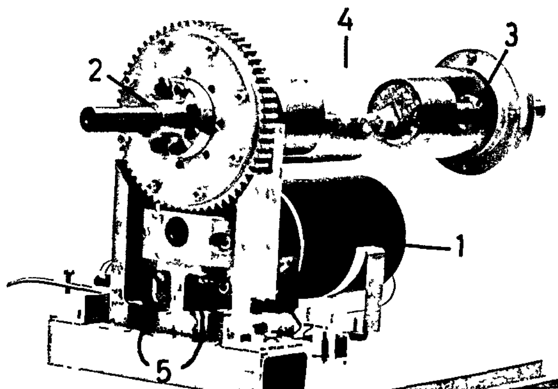


Figure 1 The torsion machine 1) Synchronous motor 2) Fixation device (rotating) 3) Fixation device (stationary) 4) Acrylic tubing 5) Strain gauges

from 2 4° to 15° per second At an angular velocity of 6° per second the maximum torque is 50 Nm The acrylic tube together with the fixation devices form a closed chamber, the environment of which can be regulated

The motor is attached to the stand by a beam During an experiment the torque of the motor causes a torque in the test body and a bending moment in the beam The strain on the beam surface to the bending moment is recorded by means of strain gauges arranged in a Wheatstone bridge (Figure 3)

As the torque in the test body is directly proportional to the bending moment in the beam the output from the bridge gives directly the torque in the test body The total deformation of the stand, beam and acrylic tube is negligible in comparison with that of the test body

The torque, as a function of time (Figure 4) is registered by means of a time base recorder fed by the signal from the strain gauge bridge

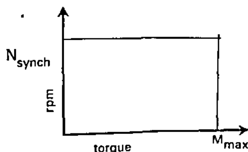


Figure 2 The action of the synchronous motor

Calibration

Before each experiment the apparatus was calibrated against a given torque of 10 Nm

For this purpose a shaft was inserted into the holes of the end plates of the acrylic tube One end of the shaft was locked to the cog wheel by a wedge In the other end there is a slit in which the mid point of an approximately 1 m long rod was fixed so that the rod axis was perpendicular to that of the shaft At one end of the rod a weight of 2 kg was suspended (Figure 5)

The apparatus was started When the rod was

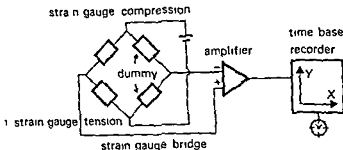


Figure 3 Wiring diagram for measuring equipment

horizontal the torsional load was 10 Nm and a reading was taken on the time base recorder An amplification was chosen to give full deflection of the recorder at about 40 Nm which corresponds to the maximum torque capacity of femora from dogs similar to those treated. The deflection written on the recording paper had full linearity *The paper speed chosen was 50 mm per second* and each second was marked on *the paper* An experiment was completed within 5 minutes after calibration

Fixation of the test bone in the torsion machine

The test bone was fixed in the torsion machine by means of two cylinders provided with concentric shafts with splines

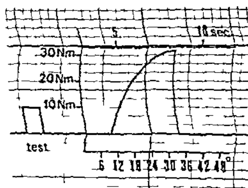


Figure 4 Example of moment time curve

The cylinders were placed in a U shaped gutter so that the surface of their casings was in line contact with the edges of the gutter The epiphyses of the test bone were each placed in the cavity of a cylinder after which the cylinders were fastened in the U shaped *gutter* by means of clamps. *The journals of the cylinders* were thus aligned concentrically The test bone with a cylinder at each end was placed in the vertical position The space between the end of the bone and the inner surface of the cylinder was successively filled with a liquid metal alloy of low viscosity Cerro Low 117 (*Mining & Chemical* Products Ltd Great Britain) (Figure 6)

This alloy is eutectic and solidifies at 47 5° C. The volume remains practically constant during solidification and in the solid state the alloy has an elastic modulus which is greater than that of cortical bone The cylinders and the liquid alloy in them were cooled to 37° C *in a* bath *of physiological* saline upon which each end of the test bone became fixed in its own metal cylinder without any residual stress or heat affecting the test bone

To prevent the metal cast from rotating *with* respect to the cylinders two screws were applied axially in the bottom of each cylinder *and fixed* into the cast metal The resulting assembly, the test bone with the *two cylinders* was mounted in the torsion *machine* The two protruding concentric *journals* of the cylinders passed through holes *in the sides of the* acrylic tube *and were* locked to these The length of the cylinders and their journals is greater than the distance be



Figure 5 Calibration of the torsion machine

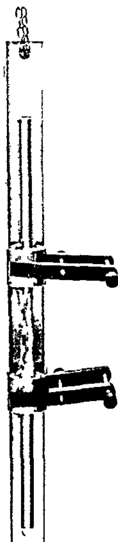


Figure 6 Holding devices in the U shaped gutter

tween the end plates of the acrylic tube. This permits investigation of bones of varying length (Figure 1).

As no relative torsional motion can occur in the joints between the test bone and apparatus the torque and angular velocity are transmitted to the test bone unaffected.

Calculation

For each experiment torque versus angular velocity was recorded. The maximum amplitude of the curve (Figure 4) (giving the maximum torque capacity) was determined to the nearest 0.1 mm. This figure was transformed to Nm by means of calibration data. The onset of torsion was noted on the recording paper as an incipient curve deviation. The distance between the starting point for incipient torsion and the projection on the zero line of the point on the curve where the resistance to torsion ends is a measure of the maximal angle of torsion which can easily be transformed to degrees. The difference in maximum torque capacity, and in maximum angle of torsion between the test bone and the control bone from the same individual has been expressed as a percentage of the value for the control bone.

Precision

The precision of the method in measuring the torsional strength of long bones was tested. Tibiae with closed epiphyseal lines from long legged healthy dogs of varying breeds and ages and of both sexes were tested as described above after the animals had been killed with an intravenous injection of thiomebumalnatrium (Pentothalsodium® Abbott Laboratories USA). All bones were subjected to medial rotation at a constant angular velocity of 6° per second until they fractured. Spiral fractures approximately in the middle of the shaft occurred in all bones. In no case were intermediate fragments obtained. After the fracture the bones were examined macroscopically and by plain radiography. No fracture fissures extending into the metal cylinders were observed.

Table 1 Maximum torque capacity of right and left tibiae of 18 dogs. The difference between right and left tibiae from the same animal is expressed as the percentage deviation from the mean of the two bones. Angular velocity 6°/s

Dog no	Right tibia Nm	Left tibia Nm	Percentage deviation from the mean of the two bones
1	13.5	13.2	1.1
2	10.0	10.1	0.5
3	16.2	15.6	1.9
4	18.6	18.3	0.8
5	21.3	22.5	−2.7
6	18.4	20.9	−6.4
7	15.8	15.8	0.0
8	15.3	14.6	2.3
9	11.7	11.5	0.9
10	24.9	25.4	−1.0
11	19.1	19.1	0.0
12	18.2	19.8	−4.2
13	17.3	17.3	0.0
14	34.4	33.5	1.2
15	31.0	31.5	0.8
16	13.7	13.6	0.4
17	28.2	27.5	1.2
18	12.1	12.5	−1.6

The maximum torque capacity was determined in 36 tibiae from 18 dogs and the differences in this respect between bones from the same dog were observed (Table 1). The highest and lowest torques measured at the time of fracture in this series were 34.4 and 10.0 respectively. The difference in torsional strength between the right (X_1) and left (X_2) tibiae in per cent of the mean value for one animal was calculated by the formula $d = \frac{X_1 - X_2}{(X_1 + X_2)\ 0.5} \cdot 100$. The mean value for the right tibia was 0.8 per cent lower than that for the left, but this difference is not significant ($P > 0.05$). By means of the formula $\sqrt{\frac{\Sigma d^2}{2n}}$ where n is the number of measured pairs of bones, the error of the method was found to be 3.1 per cent. Measurements of angles of torsion and of energy were not studied in this investigation.

To determine the possible effect of different angular velocities, the difference in torsional strength between tibiae from the same dog was calculated as above, but with one angular velocity for one tibia and another velocity for the other. Eighteen tibiae from nine dogs were studied. The material was thus divided into two groups so that the right and left tibiae of the same dog were never in the same group. In one group the torsional strength was measured at an angular velocity of 6°/s and in the other at velocities of 3, 6 and 12°/s (Table 2). The difference between the right and left tibia from the same animal is expressed as the percentage deviation from the mean of the two bones (Table 2).

Table 2. Maximum torque capacity for right and left tibiae at various angular velocities. The difference between right and left tibiae from the same animal is expressed as the percentage deviation from the mean of the two bones

Dog no.	Group I degr./s	Group I Nm	Group II degr./s	Group II Nm	Percentage deviation from the mean of the two bones
101	6	13.2	3	13.7	−1.8
102	6	28.8	3	28.0	1.4
103	6	17.6	3	17.5	0.3
104	6	15.5	6	16.1	−1.9
105	6	11.3	6	11.7	−1.7
106	6	17.3	6	17.0	0.9
107	6	22.7	12	22.7	0.0
108	6	21.2	12	21.2	0.0
109	6	21.8	12	21.4	0.9

Halving or doubling of the angular velocity of 6°/s had no appreciable effect on the torque required for fracture: all deviations from the mean value for the two bones of the same animal were smaller than 1.9 per cent (Table 2) (cf. Burstein & Frankel 1968).

Table 3. Applied and recorded torque showing the good linearity of the measuring equipment

Observation no.	Applied torque Nm	Recorded torque Nm
1	40.0	40.0
2	38.4	38.2
3	37.6	37.4
4	36.8	36.4
5	34.4	34.1
6	32.0	31.7
7	29.6	29.1
8	26.4	26.2
9	23.2	23.1
10	20.0	19.9
11	16.0	16.1
12	12.0	12.3
13	8.0	8.2
14	4.0	4.1
15	0.0	0.0

Linearity

The linearity of the equipment for measurement of maximum torque capacity was determined in the range from 0 Nm to 40 Nm at random intervals. For this a 1 metre long steel rod was inserted into the torsion machine perpendicularly to the rotation shaft with its midpoint fixed in the mobile fixation device. The rod was then loaded with different loads of known magnitude placed at one end of the rod, and the recordings were read off.

The results showing the good linearity of the measurement equipment are given in Table 3 and Figure 7.

DISCUSSION

The strength is one parameter for the experimental assessment of the results of different methods of fracture treatment in long bones. In this case the torsional strength is most suitable for the follow-

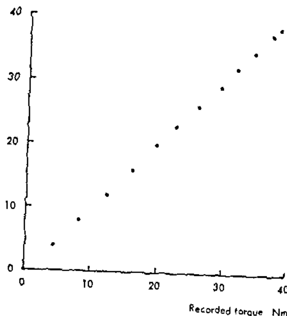


Figure 7 Linearity of the torsional measurement equipment The applied known torques are given on the ordinate and the recorded torques on the abscissa

ing reasons (cf Burstein & Frankel 1971)

1. The torque is constant in every section of the test body,
2. Minor variations in the geometry of the bone have little effect on the torsional strength,
3. The torque and angular velocity are easily measured,
4. Torsional moments occur in the majority of the types of force that cause fractures clinically (cf Asang 1974, Braden et al 1973, Frankel & Burstein 1965, McElhaney & Byars 1966, Mather 1967, Mather 1967)

Table 4 Component data

Torsion machine
Max torque 50 Nm
Revolutions 1 rpm
Stiffness of acrylic plastic tube 0 004°/Nm
Power source
Synchronous motor type R 864 Neckar Motoren, Karl Jauch & Co Postfack 21 7212 Deisslingen, W Germany
Revolutions 1500 rpm
Torque 700 cmp
Power 12 Watt
Voltage 220 Volt 50 Hz
Gear
Type 78, Neckar Motoren, Karl Jauch & Co
Gear ratio 300 1
Efficiency 90 per cent
Strain gauge
Type F–10, Showa–Soli, Toyota Central Research and Development Inc, 12 Hisakata 2 – Chome, Showa – Q Nagoya Japan
Length 10 mm
Resistance 119 8 ohm
Gauge factor 2 11

Signal generator
Type 1308–A, Audio Oscillator and Power Amplifier, General Radio Company, West Concord Massachusetts, USA

Time base recorder
Model 7–B Polygraph with model 7 PIC pre amplifier, Grass Instruments, Quincy, Massachusetts, USA

Metal alloy
Cerro Low 117, Mining & Chemical Products Ltd, Alperton Wembley, Middlesex, Great Britain
Components Bi Pb, Sn, Cd In
Melting point 47 5° C (eutectic)
Modulus of elasticity 29500 Nm/mm²
Expansion expands somewhat during solidification to 0 02 per cent after 6 minutes then shrinks, after 30 minutes the volume change is ± 0 0 per cent and after 2 hours it is stabilized at — 0 02 per cent

We have performed pilot studies in which different fixation devices have been tested In these experiments, residual stresses in bone and fixation devices have affected the results in an unacceptable way Fixation with pins passing through the bone, or with attached joints, affects the stress distribution and thus the measured torsional strength of the test bone The resulting residual stresses are of sufficient magnitude to affect the fracture course even before the test We have not succeeded in standardizing these fixation methods In order to eliminate these sources of error, we cast the ends of the bone in a mould of epoxy resin In this way we achieved a joint consisting of a mechan-

ical fixation device acting upon the epoxy resin sleeve This method had its drawbacks, however The rapidly solidifying epoxy resin did not acquire a satisfactory modulus of elasticity within the desired time under physiological temperature conditions Changes in the environment of the bone influenced its strength (Sedlin & Hirsch 1966) Heat, drying and mechanical stress each had their own significant effect These sources of error were minimized by the use of Cerro Low 117, as described above and by performing the experiments in a temperature controlled humid chamber

Our tests demonstrate the good linearity of the torsional measurement equipment and the good reproducibility of the method The agreement between the right and left tibiae with respect to maximum torque capacity justifies the use of the method in experimental studies of changes in maximum torque capacity in one bone with the other, contralateral bone from the same dog serving as a control With this method it is possible, with high precision and under standardized conditions quickly to carry out studies of bone strength *in vitro* before postmortem changes of any importance occur and without subjecting the bone to any damage that may alter its physical properties

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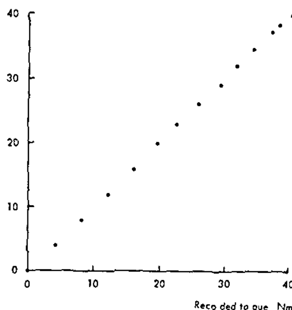


Figure 7 Linearity of the torsional measurement equipment The applied known torques are given on the ordinate and the recorded torques on the abscissa

ing reasons (cf Burstein & Frankel 1971)

1 The torque is constant in every section of the test body,
2 Minor variations in the geometry of the bone have little effect on the torsional strength
3 The torque and angular velocity are easily measured
4 Torsional moments occur in the majority of the types of force that cause fractures clinically (cf Asang 1974 Braden et al 1973, Frankel & Burstein 1965 McElhaney & Byars 1966 Mather 1967, Mather 1967)

We have performed pilot studies in which different fixation devices have been tested In these experiments residual stresses in bone and fixation devices have affected the results in an unacceptable way Fixation with pins passing through the bone or with attached joints, affects the stress distribution and thus the measured torsional strength of the test bone The resulting residual stresses are of sufficient magnitude to affect the fracture course even before the test We have not succeeded in standardizing these fixation methods In order to eliminate these sources of error, we cast the ends of the bone in a mould of epoxy resin In this way we achieved a joint consisting of a mechan

Table 4 Component data

Torsion machine
Max torque 50 Nm
Revolutions 1 rpm
Stiffness of acrylic plastic tube 0 004°/Nm
Power source
Synchronous motor type R 864 Neckar Motoren Karl Jauch & Co Postfach 21 7212 Deisslingen W Germany
Revolutions 1500 rpm
Torque 700 cmp
Power 12 Watt
Voltage 220 Volt 50 Hz
Gear
Type Z8 Neckar Motoren Karl Jauch & Co
Gear ratio 300 1
Efficiency 90 per cent
Strain gauge
Type F-10 Showa-Sokki Toyota Central Research and Development Inc 12 Hata 2 – Chome Showa – Q Nagoya Japan
Length 10 mm
Resistance 119 8 ohm
Gauge factor 2 11

Signal generator
Type 1308-A Audio Oscillator and Power Amplifier General Radio Company West Concord Massachusetts USA

Time base recorder
Model 7-B Polygraph with model 7 PIC preamplifier Grass Instruments Quincy Massachusetts USA

Metal alloy
Cerro Low 117 Mining & Chemical Products Ltd Alperton Wembley Middlesex Great Britain
Components Bi Pb Sn Cd In
Melting point 47 5° C (eutectic)
Modulus of elasticity 29500 Nm/mm²
Expansion expands somewhat during solidification to 0 02 per cent after 6 minutes then shrinks after 30 minutes the volume change is ± 0 0 per cent and after 2 hours it is stabilized at — 0 02 per cent

Table 1 Values of plasma components during the early phases of the healing of femoral and tibial fractures in man

Plasma component	Normal values	Control	Days after fracture 3	10	20	30
Calcium	4 5–5.8 mEq/l	4 85+0 509	4 94+0 554	4 96±0 175	4 94±0 221	5 01±0 554
Phosphates	2–4 mg/100 ml	2 41±0 538	3 71±0 509	3 87±0 475	4 16±1 485	3 81±0 519
Alkaline phosphatase	3 13 units K A	8 61±2 75	7 50±5 39	9 49±2 09	8 04±5 98	8 63±3 19
Plasma hydroxyproline	8.3 mg/ml	11.32±2 45	14 69±3 95	14 69±2 57	14 95±3 49	12 68±1 35
Total proteins	6 8 g 100 ml	8 00+0 707	7 28±0.36	7 04±0 721	7 42±0 565	7 65±0 50
Albumin	4 5 7 g/100 ml	5 16±0 565	4 58±0 098	4 31±0 721	4 31±0 509	4 70±2 666
Globulin	1 5–3 g/100 ml	2 84±0 01	2 70±0 099	2 73±0 435	2 85+0 028	2 39±0 80

writers maintain that the plasma phosphatase activity and the calcium and phosphatase levels are not altered (Aegerter & Kirkpatrick 1968 Anderson 1967) In spite of these speculations changes in these values have been noted in other experimental works (Studer 1965 Struck et al 1970 Nilssen & Westlin 1972 Heinemann et al 1973) Circulating hydroxyproline seems to increase also after a fracture (Klein 1966 Fazakas et al 1969 Struck et al 1970 Lyritis et al 1975)

The response to fracture healing of the plasma proteins seems to be more specific and a decrease in albumin with a simultaneous increase in the a_2 and a globulins has been reported this occurring between the 4th and 10th day after fracture (Studer 1965 Herold et al 1968)

In the present series there is evidence that the homeostasis of the plasma components prevents most of them from showing a clear response to fracture at least during the early phases of the phenomenon Plasma hydroxyproline increases but less noticeably than in similar experimental studies (Lyritis et al 1975) A change of C-reactive protein to positive is considered to be a reaction of the body to the inflammation occurring at the fracture site (Anderson & McCarty 1950)

ACKNOWLEDGEMENTS

This work was carried out with the technical assistance of Miss I Gotsi and Mr P Droutsas

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Acta orthop scand 47, 264–266, 1976

THE VALUES OF SOME PLASMA COMPONENTS DURING THE EARLY PHASES OF FRACTURE HEALING IN MAN

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A study of plasma components during the early phases of fracture healing in man showed no specific changes except a change of C reactive protein to positive and a slight but non significant increase of the plasma hydroxyproline

Key words plasma components, fracture healing, calcium, alkaline phosphatase activity, plasma hydroxyproline, C reactive protein

Accepted 17 xi 75

As a part of the body's physiological reaction to fracture, alterations of some plasma components have been reported (Bruce & Strachan 1967, Herold et al 1968, Gudmundson & Semb 1971 a, b) On the other hand classical papers state that plasma homeostasis prevents such a phenomenon occurring (Aegerter & Kirkpatrick 1968)

MATERIAL AND METHODS

Normal values for the plasma components in 13 healthy persons (6 male and 7 female) varying in age from 21 to 63 years (average 45 5 years) were measured A total of 19 patients of both sexes (9 male and 10 female) with femoral or tibial fractures and an average age of 47 5 years (varying from 18 to 70) were included in this study Blood samples were taken on days 3, 10, 20 and 30 after the fracture, for the determination of plasma hydroxyproline (Prockop & Underfriend 1960), calcium (Clark & Collip 1925), phosphate, alkaline phosphatase (King 1953), plasma proteins (biurate method) and C-reactive protein (precipitation in capillary tubes, Anderson & McCarty 1950)

RESULTS

All the results are shown in Table 1 The calcium level, alkaline phosphatase activity and plasma proteins did not change while a small increase in the phosphatase level did not surpass normal values In about half of the cases C-reactive protein was found positive Plasma hydroxyproline did not show a significant elevation

DISCUSSION

An increase in the alkaline phosphatase activity, calcium, and inorganic phosphorus has been found in the callus soon after a fracture (Bruce & Strachan 1967 Semb & Gudmundson 1969, Rackallio & Makinen 1969, Hekkelman 1970, Gudmundson & Semb 1971 a, b) Collagen is also produced at the fracture site and hydroxyproline values are found to be elevated (Stracher & Firschein 1967)

On the other hand, the metabolic response to fracture is not clear, and many

Table 1 Values of plasma components during the early phases of the healing of femoral and tibial fractures in man

Plasma component	Normal values	Control	Days after fracture			
			3	10	20	30
Calcium	4 5–5 8 mEq/l	4 85±0 509	4 94±0 554	4 96±0 175	4 94±0 224	5 01±0 554
Phosphates	2–4 mg/100 ml	2 41±0 538	3 71±0 509	3 87±0 475	4 16±1 485	3 81±0 519
Alkaline phosphatase	3–13 units K A	8 61±2 75	7 50±5 39	9 49±2 09	8 04±5 98	8 63±3 19
Plasma hydroxyproline	8.3 mg/ml	11 32±2 45	14 69±3 95	14 69±2 52	14 95±3 49	12 68±1 35
Total proteins	6 8 g/100 ml	8 00±0 707	7 28±0 36	7 04±0 721	7 12±0 565	7 65±0 50
Albumin	4–5 7 g/100 ml	5 16±0 565	4 58±0 028	4 31±0 721	4 31±0 509	4 70±2 666
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writers maintain that the plasma phosphatase activity and the calcium and phosphatase levels are not altered (Aegerter & Kirkpatrick 1968, Anderson 1967) In spite of these speculations, changes in these values have been noted in other experimental works (Studer 1965, Struck et al 1970, Nilssen & Westlin 1972, Heinemann et al 1973) Circulating hydroxyproline seems to increase also after a fracture (Klein 1966, Fazakas et al 1969, Struck et al 1970, Lyritis et al 1975)

The response to fracture healing of the plasma proteins seems to be more specific, and a decrease in albumin with a simultaneous increase in the a_1 and a globulins has been reported, this occurring between the 4th and 10th day after fracture (Studer 1965, Herold et al 1968)

In the present series there is evidence that the homeostasis of the plasma components prevents most of them from showing a clear response to fracture, at least during the early phases of the phenomenon Plasma hydroxyproline increases, but less noticeably than in similar experimental studies (Lyritis et al. 1975) A change of C reactive protein to positive is considered to be a reaction of the body to the inflammation occurring at the fracture site (Anderson & McCarty 1950)

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Acta orthop scand 47, 267-270, 1976

THE PENETRATION OF LINCOMYCIN INTO NORMAL HUMAN BONE

Determinations of Penetration into Compact Bone, Spongy Bone and Bone Marrow

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The penetration of lincomycin into normal bone was studied in 10 patients with fracture of the neck of the femur, a separate determination being made of the lincomycin concentration in serum bone marrow spongy bone and compact bone The concentration of lincomycin in bone marrow was found to be at the same level as that in the serum The concentration in spongy bone amounted in most cases to 50 to 75 per cent of the concentration in the serum, whereas the concentration in compact bone varied from 0 to 15 per cent of that in the serum

Key words lincomycin bone tissue bone marrow, compact bone, spongy bone

Accepted 15 xii 75

Since lincomycin became available at the beginning of the 60's (Mason et al 1963), this antibiotic has acquired a leading role in the treatment of acute and chronic osteomyelitis A number of investigations have been done to elucidate the ability of lincomycin to penetrate bone These studies, animal experiments (Grady & Stern 1965, Evaskus et al 1969) as well as studies of its penetration into human bone (Mason et al 1963, Holloway et al 1964, Geddes et al 1967, Vacek et al 1967), have shown somewhat varying relationships between the concentrations of lincomycin in serum and in bone, and cannot validly be compared This is because various types of bone have been investigated, and also because different and often very inadequately described homogenization procedures have been employed

The aim of the present study was to examine the penetration of lincomycin into normal human bone, employing a well defined, reproducible homogenization procedure A further aim was to examine separately the penetration of lincomycin into bone marrow, spongy bone and compact bone

MATERIAL AND METHODS

Material The material consists of 10 patients two men and eight women, aged 50 to 89 years mean age 72 4 years All patients had a unilateral fracture of the neck of the femur In four patients, alloplasty *ad modum* Moore was performed and six patients had a MacLaughlin

osteosynthesis The osteosynthesis was performed on average 4 days after the fracture All patients had normal renal function, evaluated by two determinations of serum creatinine

Bone biopsies The biopsies were obtained peroperatively from the proximal end of the femur as soon as the bone was exposed for the commencement of the osteosynthetic or alloplastic procedure A block of compact bone was removed about 1 cm³ in size, and this was immediately cleaned of periosteum spongy bone and blood By means of a curette, spongy bone was taken from the inner surface of the femur Finally, bone marrow was aspirated through a metal cannula the position of which was monitored by fluorescent screening In all cases the aspirate was typical for bone marrow i e, there was an admixture of fat and bony trabeculae All bone biopsies were obtained from macroscopically normal bone some distance from the line of fracture

Serum concentration determination Blood samples to determine the serum concentration of lincomycin were drawn twice before and twice after the bone biopsies were obtained at intervals of ½ to 1 hour

Intake of lincomycin The lincomycin was administered as lincomycin chloride (Lincocin®) intramuscularly, in doses of from 13 mg to 24 mg per kg per 24 hours, as two doses at intervals of 12 hours (Table 1) Table 1 also shows the duration of treatment

Homogenization procedure Samples of bone marrow were homogenized undiluted in a Potter Elvehjem homogenizer A vibration mill was employed to homogenize the spongy bone and the compact bone This method of homogenization has been described in detail in a previous study (Hansen et al 1975) The method permits reproducible homogenization to a particle size of 0 3-3 2 μ

Barteriological method A microbiological method was employed to determine the lincomycin concentration using *Sarcina lutea* ATCC 9341 as test organism and Antibiotic Medium No 4 (Difco) as medium Serum and marrow specimens were examined using disc plate" diffusion method whereas the specimens of compact bone and spongy bone were examined using the agar cup diffusion technique The plates were seeded with broth culture in dilution 1 6 after incubation for 24 hours at 37° C. The detailed principles have been described previously (Nielsen & Hansen 1972) The lower limit for sensitivity in the two methods was 1 5 and 0 30 μg/ml respectively Bone marrow and serum were examined undiluted Compact bone and spongy bone were examined after dilution with phosphate buffer (pH 7 8) in the proportion 1 3 and 1 5 respectively Standard solutions of lincomycin in pooled human serum were used for examining serum and marrow Standard solutions of lincomycin in phosphate buffer were used for examining compact bone and spongy bone studies also being made in which homogenized antibiotic free bone was added to the standard solutions

In three patients who had *not* received any lincomycin specimens of serum bone marrow spongy bone and compact bone had no anti

Table 1 Concentrations of lincomycin in serum (μg lincomycin per ml serum) and in bone tissue (μg lincomycin per g tissue) 3-9 hours after the final intramuscular administration of lincomycin Serum concentrations were determined at intervals of ½-1 hour before and after time of biopsy of bone tissue

Pt no	Age	Sex	Intake of lincomycin (mg per kg body weight per 24 h)	Days of treatment with lincomycin	Lincomycin in serum at time of biopsy of bone tissue (μg/ml)	Lincomycin in bone marrow (μg/g)	Lincomycin in spongy bone (μg/g)	Lincomycin in compact bone (μg/g)
1	59	M	23	1	5 9	9 5	5 9	1 4
2	74	F	20	1	7 3	5 8	4 4	<1 2
3	56	F	23	1	10 3	11 5	6 5	<1 0
4	77	F	20	5	12 0	10 0	7 7	<1 0
5	89	F	20	5	12 1	14 3	11 0	<1 0
6	70	F	13	3	14 8	13 8	10 7	<1 2
7	76	M	17	1	15 2	14 0	6 8	<1 2
8	87	F	24	1	15 8	14 7	5 2	1 8
9	50	F	16	2	20 2	14 5	11 0	<1 0
10	86	F	20	1	20 2	14 4	4 8	2 2

bacterial effect on the test bacterium used to determine the concentrations of lincomycin

RESULTS

Table 1 shows the concentrations of lincomycin in serum, in bone marrow, in spongy bone and in compact bone. There is no significant difference between the concentrations of lincomycin in serum and in bone marrow (Wilcoxon test for pair differences, $P > 0.10$). In seven patients the concentration of lincomycin in the bone marrow was at the same level as the serum concentration, while in one patient it was more than 50 per cent higher and in two patients 30 per cent lower. The median content of lincomycin in bone marrow was 93 per cent of that in serum (range 71–161 per cent).

Concentrations of lincomycin in spongy bone were significantly lower than concentrations in serum and bone marrow (Wilcoxon test for pair difference, $P < 0.01$ for both comparisons). The median content of lincomycin in spongy bone amounted to 62 per cent of that in serum (range 24–100 per cent), and to 59 per cent of that in bone marrow (range 33–77 per cent). In compact bone, concentrations of lincomycin were significantly lower than concentrations in serum, in bone marrow and in spongy bone (Wilcoxon test for pair differences, $P < 0.01$ for all comparisons). In seven cases lincomycin was not detectable in specimens of compact bone, in two cases it amounted to 11 per cent and in one case to 24 per cent of the corresponding serum concentrations.

DISCUSSION

The present study deals only with normal b... b... c... *Staph. aureus* (0.5 to 2 µg/ml) (Garrod & O'Grady 1972), the concentrations of lincomycin found in bone marrow were at a therapeutic level (MIC × 5). The concentrations found in spongy bone were at the therapeutic level for Staph. aureus strains with an MIC ≦ 1 µg/ml. It nevertheless appears reasonable to assume that the concentration of lincomycin in spongy bone at the peak period is considerably higher, so that a therapeutic level is achieved in the case of strains with an MIC of 2 µg/ml. The concentrations in compact bone, on the other hand, are considerably below the therapeutic level.

Investigations attempting to measure separately the concentrations of lincomycin in bone marrow, spongy bone and compact bone, have not previously been carried out. In an examination of the lincomycin content of total bone (spongy bone + compact bone) Varek et al. (1967) found that following the intake of varying amounts of lincomycin in 33 patients, in three cases the lincomycin concentrations in bone were greater than the corresponding serum concentrations, in one case the concentration in bone and serum was the same, and in 29 cases the concentration of lincomycin in bone was lower than in serum. In these latter cases, the concentration of lincomycin in the bone was in most cases one fifth to one third of the corresponding serum concentration. The type of bone investigated in the individual cases is not stated. Geddes et al. (1967) investigated 12 non-infected patients who underwent elective orthopaedic surgery. The type of bone investigated is not stated, but presumably total bone was involved. In three cases, the concentrations found in the bone were higher than the corresponding serum concentrations, in the remaining cases the concentrations in bone were generally one quarter to one third of the corresponding serum concentrations. Linzenmeier et al. (1968) examined the content of lincomycin in infected bone from 30 patients with

chronic osteomyelitis or gangrene, following the intake of varying doses of lincomycin It was not reported whether spongy bone or compact bone was employed In two cases, the results showed concentrations in bone which were higher than the corresponding serum concentrations, while in 28 patients the concentration of lincomycin in bone was lower than the serum concentration, and in most cases amounted to one third to two thirds of this value

Evaskus et al (1969) carried out *animal experiments*, and found that in rats there was a considerable difference in the penetrating power of lincomycin into bone with a large proportion of spongy bone (femur) and bone with a small spongy bone content (mandible) At intervals of ½ and 2 hours after intramuscular administration, the concentrations of lincomycin found in the femur were at the same level as the corresponding serum concentrations, while after the same intervals, the concentrations found in the mandible were 25 and 0 per cent, respectively, of those in the serum

The results obtained by Evaskus et al and the present results show that in evaluating the penetration of antibiotics into bone, allowance must be made for *the composition of the bony tissue*, including under this heading the relative incidence of bone marrow, spongy bone and compact bone For similar reasons, an evaluation of the penetration of linco mycin into pathological bone is not possible on the basis of the findings in normal bone Only scanty information is available regarding the penetration into pathological bone (Mason et al 1963) A systematic investigation of the penetration of lincomycin into well defined pathological bony structures would be an advantage

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TREATMENT OF CHRONIC OSTEOMYELITIS BY TRANSPLANTATION OF AUTOGENOUS OMENTUM WITH MICROVASCULAR ANASTOMOSIS

A Preliminary Report

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Free omental transplantation with vascular anastomosis was attempted in three clinical cases as a new method of treatment for chronic osteomyelitis The bone cavity produced by debridement was completely eliminated by the transplanted omentum Furthermore, the omentum because of its biological characteristics, formed good vascular anastomoses with the adjacent bone tissue Although sufficient time has not yet elapsed to prove the existence of healthy bone regeneration and therefore further evaluation for a longer period is necessary, this therapeutic method would seem to have considerable potential in the treatment of chronic osteomyelitis

Key words omentum autologous transplantation, microsurgery, osteomyelitis

Accepted 22 i 76

Various methods have been used since the early days of medicine in an attempt to treat chronic osteomyelitis However, no ideal method has yet been established One of the most unfavourable factors making healing of chronic osteomyelitis difficult, is the ischaemia rather than the infection of the bone, because avascular bone or scar tissue acts as an impenetrable barrier to antibiotics

The principle of management, therefore, consists of debridement of sequestra scar tissue and sinuses, exposing fresh healthy bone, and then the administration of appropriate antibiotics Here the problem arises of how to eliminate the dead space upon closure of the wound, so as to prevent reinfection For this purpose various techniques have been applied, such as free skin graft, pedicle muscle flap and bone graft, which, however, are not always applicable or successful

The purpose of this paper is to describe a method, first developed by us, to utilize the omentum, rich in vascular structure, for filling the dead space The idea developed after reading a paper by McLean & Buncke (1972) and was later reinforced by Harii, one of the authors,

chronic osteomyelitis or gangrene, following the intake of varying doses of lincomycin It was not reported whether spongy bone or compact bone was employed In two cases, the results showed concentrations in bone which were higher than the corresponding serum concentrations, while in 28 patients the concentration of lincomycin in bone was lower than the serum concentration, and in most cases amounted to one third to two thirds of this value

Evaskus et al (1969) carried out *animal experiments,* and found that in rats there was a considerable difference in the penetrating power of lincomycin into bone with a large proportion of spongy bone (femur) and bone with a small spongy bone content (mandible) At intervals of ½ and 2 hours after intramuscular administration, the concentrations of lincomycin found in the femur were at the same level as the corresponding serum concentrations, while after the same intervals, the concentrations found in the mandible were 25 and 0 per cent, respectively, of those in the serum

The results obtained by Evaskus et al and the present results show that in evaluating the penetration of antibiotics into bone, allowance must be made for the composition of the bony tissue, including under this heading the relative incidence of bone marrow, spongy bone and compact bone For similar reasons, an evaluation of the penetration of lincomycin into pathological bone is not possible on the basis of the findings in normal bone Only scanty information is available regarding the penetration into pathological bone (Mason et al 1963) A systematic investigation of the penetration of lincomycin into well defined pathological bony structures would be an advantage

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cutaneous tunnel to be anastomosed with the recipient vessels. Following end to end anastomoses of the vessels the graft is well packed in the gutter In the event that there is a skin defect upon closure of the wound a split thickness skin graft is sewn into place over the omental graft with a tie over dressing

CASE REPORTS

Case 1 A 65 year old female with a history of four surgical operations for chronic osteomyelitis of the left femur from the age of 13 was referred to us with an acute exacerbation A radiograph showed a thickened and sclerotic cortex at the junction of the middle and lower thirds of the femur and a lateral cortical surface which appeared irregular (Figure 3)

At operation the affected portion was well curetted and an omental graft was placed in the gutter A branch of the lateral circumflex artery and the greater saphenous vein were used as the recipient vessels (Figure 4)

The patient received antibiotics for about 1 month prior to admission 45 days preoperatively after admission and 60 days after operation

Culture of the discharge and granulation tissue on admission and at surgery was negative for bacterial growth

A femoral arteriograph obtained 5 weeks later revealed well preserved patency of the omental artery as indicated by the arrow (Figure 5)

Now 1 year and 5 months following surgery the patient shows no systemic or local evidence of recurrent inflammation There is no radiographical evidence of bony filling as yet



Figure 3 Case 1 A radiograph of the left femur

Case 2 A 43 year old male with chronic osteomyelitis of the left tibia from the age of 11 was admitted to our clinic for operation

A radiograph indicated marked sclerosis with irregular margins of almost the entire tibia with an anterior convex deformity (Figure 6)



Figure 4 Case 1 The omental graft is in view being placed in the gutter

who reported a successful autotransplantation of the omentum with microvascular anastomosis for a large scalp defect (Haru & Ohmori 1973) According to the latter report, the omental transplant took well on the scalp and could be covered by a split-thickness skin graft

In our animal experiments, the omental transplant with microvascular anastomosis showed good viability with a well preserved vascular structure and the development of a rich vascular connection with the surrounding bone tissue (Figure 1)

It was expected, therefore, that omental transplantation with vascular anastomosis could be applied to the treatment of osteomyelitis

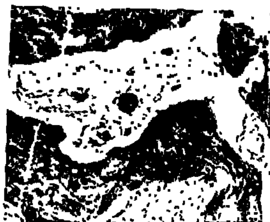


Figure 1 In an adult dog the femoral periosteum was stripped, the cortex was fenestrated and the bone marrow was completely curetted out The omental graft with vascular anastomoses was then placed in the cavity At sacrifice 5 weeks later, a microangiography of the transplanted omentum was performed via the anastomosis The vessels within the newly developed bone marrow tissue are filled with the contrast material (Haematoxylin and eosin × 80)

OPERATIVE TECHNIQUE

It is preferable to use a two team approach—one team prepares the omental graft, while the other performs debridement of the diseased area

Through an upper midline incision the greater omentum is separated from the transverse colon and the greater curvature of the stomach, and an omental graft with the right or left gastroepiploic vessels as its pedicle is obtained The size of the graft depends on the volume of the cavity to be filled (Figure 2)

The stumps of the gastroepiploic vessels are irrigated by a heparinized saline solution and the graft is wrapped in a moist pad until it is placed in the gutter formed after debridement The pedicle is then brought up through a sub-

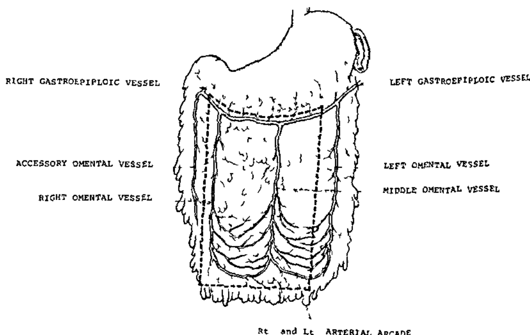


Figure 2 Blood supply of the omentum and an example of the extent of the excision

taneous tunnel to be anastomosed with the recipient vessels Following end to end anastomoses of the vessels, the graft is well packed in the gutter In the event that there is a skin defect upon closure of the wound a split thickness skin graft is sewn into place over the omental graft with a tie over dressing

CASE REPORTS

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A radiograph indicated marked sclerosis with irregular margins of almost the entire tibia with an anterior convex deformity (Figure 6)



Figure 4 Case 1 The omental graft is in view being placed in the gutter



Figure 5 Case 1 A femoral arteriograph at 5 weeks after surgery The omental artery remains patent (arrow)

The middle and lower thirds of the tibia were curetted following sufficient excision of the involved bone and the gutter was filled with an omental graft with the anterior tibial vessels being used as the recipients The skin defect over the omentum was covered by a split thickness skin graft

The patient received antibiotics for about 2 months before admission and for 20 days prior to and about 2 months after surgery in our clinic respectively Culture of the discharge on admission showed *Escherichia cloacae* and the culture at surgery was negative

An arteriograph carried out 5 weeks postoperatively showed patency of the omental vessel

One year and three months later the patient was doing well with no evidence of recurrence X ray findings are still unchanged from the postoperative pictures

Case 3 This 27 year old male with chronic osteomyelitis of the femur from the age of 13 was transferred to our clinic because of a recent aggravation

A radiograph on admission showed sclerotic cortex extending from the middle portion to th distal metaphysis of the femur

The external pudendal artery and the grea saphenous vein were used as the recipients f the omental grafting in this case

Antibiotics were administered 10 days prior admission and for 15 days before and about months after surgery in our clinic respect Bacterial cultures were negative both on a mission and at surgery

A femoral arteriograph 5 weeks after surg failed to reveal the vessels of the omental graft though the clinical results had been favourab After 12 months the patient is in good con tion without any signs of recurrent inflamma tion

DISCUSSION

The omentum has the characteristic that it readily develops vascular anastomoses with adjacent tissues and this quality has been used for the revascularization of ischaemic myocardium (Vineberg et al 1965), and chronic arterial obstruction of the leg (Nishimura et al 1974)



Figure 6 Case 2 A radiograph of the left tib

etc However, reports of free omental transplantation by microsurgical techniques are still limited to only a few papers and our method of applying this technique in the treatment of chronic osteomyelitis is an entirely new attempt

One of the advantages of this method is that it is suitable for eliminating a dead space regardless of the size, shape, or site The second advantage as elicited by our animal experiments, is that the transplanted omentum forms abundant vascular anastomoses with the surrounding bone and therefore, it is expected that the bone tissue will receive a sufficient supply of blood

The patency of anastomosis was confirmed in two out of three clinical cases by femoral arteriographs performed 5 weeks postoperatively In our series of animal experiments the patency was studied at autopsy by microscopic inspection and/or by angiography via the saphenous artery, and the results were found to be excellent with the success rate being as high as 81 per cent (13 dogs out of 16)

It is likely that patent anastomosis is not always demonstrable by femoral arteriography if resistance to the blood flow is relatively high at the anastomosis site This is possibly the explanation in case 3

The disadvantages of our method are its technical difficulty and the necessity for abdominal exploration

The recipient arteries sacrificed for end to-end anastomosis were a branch of the lateral circumflex artery in case 1 the anterior tibial in case 2, and the external pudendal in case 3 The objection may be raised that sacrificing the anterior tibial artery might cause some degree of ischaemia of the pretibial muscle group Harii et al, however, demonstrated that no ischaemia has ever occurred following the transplantation of a groin flap a procedure which also uses the anterior tibial artery In addition, the postoperative arteriograph in case 2 revealed the contrast material filling the anterior tibial artery distal to the sectioned point via collateral circulation

Furthermore, performing a popliteal arteriography (with a 50 per cent suspension of barium sulphate in 3 per cent gelatin) in an amputated leg after cutting the anterior tibial artery, in the same way as carried out in case 2, a relatively good distribution of the radio-opaque material in the pretibial muscles was shown on a cross section radiogram It is likely, therefore, that the transsection and ligation of several branches of the anterior tibial artery in preparation for grafting does not result in significant ischaemia in any part of the pretibial muscles

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Acta orthop scand 47, 276–282, 1976

THE VALUE OF LOW DOSAGE HEPARIN FOR THE PROPHYLAXIS OF THROMBOEMBOLISM IN PATIENTS WITH TRANSCERVICAL AND INTERTROCHANTERIC FEMORAL FRACTURES*

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One hundred and ten female patients, over the age of 60, with inter trochanteric or transcervical femoral fractures were included in a controlled, randomized, clinical trial investigating the value of low dosage heparin in the prophylaxis of deep vein thrombosis There were 50 completed pairs Eight (16 per cent) deep vein thromboses occurred in the heparinized group compared with 23 (46 per cent) deep vein thromboses in the control group The incidence of pulmonary embolism was also reduced The diagnosis of deep vein thrombosis was made on clinical grounds, supplemented by phlebography and autopsy There was no difference in the wound haematoma or infection rate The heparin was commenced on admission to hospital and it is suggested that in this group of patients low dosage heparin prophylaxis should start on admission and not wait until surgery

Key words thromboembolism prophylaxis, low dosage heparin, transcervical femoral fractures, intertrochanteric femoral fractures

Accepted 20 xii 75

Deep vein thrombosis is a frequent complication of fractures of the proximal femur Using phlebography, Smyrnis et al (1973) found that deep vein thrombosis had occurred in 60 3 per cent of 58 patients with a fracture of the upper end of the femur Sevitt & Gallagher (1959) showed that pulmonary embolism was a common cause of death in these patients Low dosage heparin prophylaxis, which was introduced by Sharnoff & De Blasio (1970), has been found to be a useful method of diminishing the incidence of deep vein thrombosis, following a variety of surgical procedures (Kakkar et al 1971, Williams 1971, Gordon-Smith et al 1972, Kakkar et al 1972) However, little work has been done on its role in patients who have sustained a fracture of the proximal femur This study was carried out to determine the value of low dosage heparin for the prophylaxis of thromboembolism in patients with trans

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cervical or intertrochanteric femoral fractures

PATIENTS AND METHODS

Female patients over the age of 60 years who were ambulant before the injury and who had sustained intertrochanteric or transcervical femoral fractures were entered into a controlled, randomized clinical trial Patients who were under the age of 60 who had a history of deep vein thrombosis pulmonary embolism haematemesis haematuria or other bleeding disorders and patients with malignant disease were excluded from the trial Male patients were also excluded so that all the patients could be admitted into one ward thus standardizing the nursing care Patients were stratified according to age and surgical procedure creating six subgroups (Table 1) The patients were randomly allocated to one of two treatment groups The first received heparin (BP) 5000 units 12 hourly by deep subcutaneous injection into the abdominal wall the injections commencing on admission to hospital and continuing until the patient was discharged transferred or fully mobilized The second group served as controls The nursing care was identical in both groups as was the postoperative mobilization The operative procedure was the same Drains were not used and postoperatively all patients were placed in a cottonwool and crepe bandage hip spica for 48 hours

Deep vein thrombosis was diagnosed by clinical and venographic techniques Each patient was examined daily A positive clinical diagnosis required the presence of peripheral oedema or a 1.5 cm or greater difference in calf circumference in addition to calf or femoral vein tenderness a positive Homan's sign or pyrexia which otherwise was not explicable. When only peripheral oedema or a difference in calf circumference was found phlebography was carried out Some patients who had a definite clinical diagnosis also underwent phlebography and in these patients the clinical diagnosis was confirmed Pulmonary embolism was diagnosed on clinical and radiological examination or at autopsy Lung scans were not used routinely

Table 1 Stratification of the trial

	60–74 years	75 years+	Total
Nail fixation only	5	16	21
Nail + plate fixation	8	16	24
Austin Moore replacement arthroplasty	0	5	5
Total	13	37	50

The number of pairs of patients who were included in each sub-group of the clinical trial.

RESULTS

The results are shown in Table 2 One hundred and ten patients were admitted into the trial and this included 50 randomized, stratified pairs The results have been determined in these 50 pairs There were 8 (16 per cent) deep vein thromboses in the heparin treated group compared with 23 (46 per cent) deep vein thromboses in the control group This difference is statistically significant ($P < 0.001$) Three patients developed late deep vein thromboses, i e thromboses which were found either clinically or at autopsy at least 6 weeks after surgery, where there had been no evidence of deep vein thrombosis in the intervening period and, if the patient was on heparin, after it had been discontinued There was one late deep vein thrombosis in the heparin group and two in the control group There was one pulmonary embolus (2 per cent) in the heparin treated group and two (4 per cent) in the control group In addition there were four late pulmonary emboli These were pulmonary emboli which were found clinically or at autopsy at least 6 weeks after the patient had undergone surgery and where there was no clinical or radiological evidence of the pulmonary embolus in the intervening period One occurred in a patient who had been on heparin therapy and which had been discontinued when she was mobilized The other three occurred in control patients There were 15 deaths in the heparin group and 11 in the control group All deaths which occurred within 3 months of surgery are included Ten of the patients in the heparin group died from

Table 2

	Heparin treated		Control	
No of paired patients	50		50	
Deep vein thrombosis	8 (16%)*		23 (46%)*	
Pulmonary embolism (Early)	1 (2%)	2 (4%)	2 (4%)	5(10%)
(Late)	1 (2%)		3 (6%)	
Deaths	15 (30%)		11 (22%)	
Wound infection/haematoma	7 (14%)		8 (16%)	
Haematuria	2 (4%)		0	
Cerebrovascular accident	0		1 (2%)	

The results obtained in the 100 paired patients
* This difference is significant ($P < 0\ 001$)

pneumonia, one from a myocardial infarct, one from pyelonephritis and a cerebral abscess, one following intestinal obstruction and two from pulmonary emboli—at 8 days and 6 weeks Two patients had a deep vein thrombosis demonstrated at autopsy Five control patients died from pneumonia, one from a myocardial infarction and five with pulmonary emboli—at 11 days, 4 weeks, 6 weeks, 7 weeks and 8 weeks, respectively In seven patients deep venous thromboses were present at autopsy

There were no complications as a result of the heparin therapy The only patient who had a cerebral vascular bleed was in the control group, but two heparinized patients developed haematuria The presence of a haematoma and superficial wound infection often occurred simultaneously and these complications, therefore, were considered together Seven patients in the heparin group developed a haematoma and/or superficial wound infection compared with eight patients in the control group No patient developed deep infection

There were 13 pairs between the ages of 60 and 74, and 37 pairs were 75 years or older The results in these two subgroups are shown in Table 3 The incidence of deep vein thrombosis was higher in the younger age group but again was much less marked in the heparinized patients In the younger age group, there were three (23 1 per cent) deep vein thromboses in the heparin group compared with eight (61 5 per cent) in the control group In the older age group there were five (13 5 per cent) deep vein thromboses in the heparin group and 15 (40 5 per cent) in the control group

The results varied in the different surgical groups and are shown in Table 4 The incidence of deep vein thrombosis was much higher in those patients whose fracture was fixed with a nail and plate

Table 3 The incidence of Deep Vein Thrombosis (D V T) in the two age groups

	60–74 years		75 years and over	
	No of patients	No D V T	No of patients	No D V T
Heparinized	13	3 (23 1%)	37	5 (13 5%)
Control	13	8 (61 5%)	37	15 (40 5%)
Total	26	11 (42 1%)	74	20 (27 0%)

Table 4 The incidence of Deep Vein Thrombosis associated with the different surgical procedures

	Nail fixation		Nail + plate fixation		Replacement arthroplasty	
	No of patients	No of DVT	No of patients	No of DVT	No of patients	No of DVT
Heparinized	21	1 (4 8%)	24	7 (29 2%)	5	0 (0%)
Control	21	5 (23 8%)	24	15 (62 5%)	5	3 (60%)
Total	42	6 (14 3%)	48	22 (45 8%)	10	3 (30%)

than in those whose fractures were fixed with a nail In 21 pairs the fracture was fixed with a nail There was one (4 8 per cent) deep vein thrombosis in the heparin group and five (23 8 per cent) deep vein thromboses in the control group Twenty four pairs of patients had their fracture fixed with a nail and plate There were seven (29 2 per cent) deep vein thromboses in the heparin and 15 (62 5 per cent) deep vein thromboses in the control group Only five pairs of patients had a primary Austin Moore replacement arthroplasty The numbers are too small for comparison with the other groups of patients but neverthe less there was still a marked difference between the control and heparin groups There were no deep vein thromboses in the treated group compared with three (60 per cent) in the control group

DISCUSSION

Patients who sustain an intertrochanteric or transcervical femoral fracture generally tend to be elderly and ill, and the injury is associated with a high mortality and morbidity The development of a painful deep vein thrombosis or a swollen limb secondary to a deep vein thrombosis interferes with their rehabilitation whereas an asymptomatic minor thrombosis in the soleal venous plexus does not affect their mobilization For this reason the diagnosis of deep vein thrombosis was based on clinical findings supplemented by phlebography or autopsy Similar diagnostic criteria were used by Kline and his colleagues (Kline et al 1975) in their study

During the past few years several methods of deep vein thrombosis prophylaxis have been described Calf compression or stimulation is largely impracticable in patients undergoing hip surgery and was not considered for this study

Anticoagulation is probably the most established form of prophylaxis Sevitt & Gallagher (1959) investigated 300 patients, over the age of 55, with a transcervical or intertrochanteric femoral fracture Half the patients were anticoagulated and half acted as controls Four (2 7 per cent) clinically detectable deep vein thromboses occurred in the anticoagulated group compared with 43 (29 per cent) in the control group There were 25 deaths in the treated and 42 in the control group Autopsy study disclosed deep vein thromboses in three out of 21 (14 per cent) anticoagulated patients compared with 29 thromboses in 35 control patients (83 per cent) Three anticoagulated patients were found to have a pulmonary embolism In two it was large and thought to have contributed to the cause of death There were 21 pulmonary emboli including 15 major ones found at autopsy in the control group

Salzman et al (1966) also investigated the use of anticoagulants in 166 patients with proximal femoral fractures They found two (2 4 per cent) deep vein

thromboses in the 83 anticoagulated patients and 22 (26.5 per cent) venous thromboses in their control group. There was one pulmonary embolus (1.2 per cent) in the anticoagulated and eight (9.6 per cent) in the control group. However, they found that anticoagulation was associated with an increase in the wound haematoma rate. There were 29 wound haematomata (34.9 per cent) in the anticoagulated group compared with 20 (24 per cent) in the control group.

In addition to the increased risk of wound haematoma formation, the level of anticoagulation may be difficult to regulate. There is no standard dose, different patients react differently to the same dose and the same patient may react differently on a different occasion. Hypnotics, particularly barbiturates, tend to interfere with their action. In a retrospective study Muckle et al. (1974) found that anticoagulation reached therapeutic levels in only 169 (65 per cent) of 260 patients. The anticoagulation was inadequate in 79 and excessive in 12 patients. When it was inadequate, it did not diminish the incidence of deep vein thrombosis or pulmonary embolism and when excessive was associated with a marked increase in the incidence of wound haematoma formation. Daily estimation of the prothrombin time is essential until control is established and this requires adequate laboratory back-up facilities.

Low dosage heparin prophylaxis, introduced by Sharnoff & De Blasio in 1970, seems to overcome some of the disadvantages associated with other methods. The results obtained in a variety of trials indicate that it is a useful method of diminishing the incidence of deep vein thrombosis (Kakker et al. 1971, Williams 1971 and Gordon Smith et al. 1972). In 1973 Sharnoff stated that he had had only two failures, confirmed at autopsy, compared with more than 1,450 successfully heparinized patients. Interestingly, both failures occurred in elderly patients with a fracture of their proximal femur.

Patients who sustain intertrochanteric and transcervical femoral fractures tend to be immobile from the time of injury whereas patients who undergo major elective surgery are mobile until the time of operation. We decided, therefore, to start our heparin regimen on admission and not to wait until the patient had undergone surgery. This was not associated with any excess bleeding during the operation nor with an increased wound haematoma or infection rate. The results of our study indicate that when heparin is started at this time there is a marked decrease in the incidence of deep vein thrombosis. This is not surprising as one of the main predisposing causes of deep vein thrombosis is immobility.

One of the surprising findings in our study was that the incidence was higher in the 60–74 age group than in the over 75 year age group. Previous work had suggested that the incidence increases with increasing age (Sevitt & Gallagher 1961). Another interesting finding is that the incidence was higher in patients undergoing nail and plate fixation compared with those undergoing nail fixation of their fracture.

In our study sodium heparin (BP) was used, and the results indicate that it is as effective as the more expensive slow release calcium heparin.

Van Vroonhoven (1974), in a controlled clinical trial using I^{125} labelled fibrinogen, found that low dosage subcutaneous heparin was more effective in preventing postoperative deep vein thrombosis than routine oral anticoagulation. There was one (2 per cent) deep vein thrombosis in the 50 patients treated with heparin and nine (18 per cent) in the 50 patients who were anticoagulated.

Gallus et al. (1973) used a modified low dosage heparin regimen consisting of 5,000 units given thrice rather than

twice daily They investigated 46 patients with fractures of the proximal femur and found 13 per cent deep vein thromboses in the treated group compared with 48 per cent in their control group In this group of patients the heparin was started within 12 hours of hospitalization Although clinically significant bleeding was not increased the amount of blood required for transfusion was moderately [illegible] lower [illegible] e was [illegible] Their incidence of deep vein thrombosis in patients with fractures of their proximal femur were similar to those reported in our study both in the control and the heparin groups even though they relied on I^{125} labelled fibrinogen uptake for the diagnosis The similarity in results suggests that the efficacy of the low dosage heparin prophylaxis was due to starting treatment soon after the patient was admitted and was not due to increasing the dose of heparin to 5 000 units thrice daily Nevertheless a randomized trial comparing these two low dosage heparin regimens in patients with proximal femoral fractures may be indicated

The heparin must be continued until the patient is mobile and this may be partially responsible for the failure reported by Kakkar et al (1972)

The other major method of deep vein thrombosis prophylaxis is the use of Dextrans but they may be associated with increased wound haematoma formation and are contraindicated if the blood urea is elevated or renal function is impaired Korvald et al (1973) reported that Dextran 70 was relatively ineffective compared with the combination of Dextran 70 and Warfarin in the prophylaxis of deep vein thrombosis in patients with transcervical and intertrochanteric fractures They also found a different incidence of deep vein thrombosis in the different operative groups which was similar to that found in our study Wedge et al (1974) found that Dextran 75 did not significantly alter the thromboembolic complication rate in the patients with hip fractures These results suggest that Dextran is not as effective as anticoagulation or low dosage heparin in the prevention of deep vein thrombosis

The mechanism of action of the low dosage heparin is not certain It is thought that it decreases platelet adhesiveness and inhibits activated factor X The latter is involved in the process of coagulation Heparin in the dose used does not affect the thrombin clotting time and does not require laboratory control The heparin dose can be easily reversed and therefore can be used in patients with a past history of haematuria and other bleeding disturbances

The results of our study indicate that low dosage heparin is a useful method of diminishing the incidence of deep vein thrombosis in patients with transcervical or intertrochanteric fractures Comparison of our results with other series suggests that in these patients it is essential to start the heparin on admission to hospital When the heparin was commenced at the time of surgery, the incidence of deep vein thrombosis was not reduced Our findings also indicate that low dosage heparin is at least as good a prophylactic agent as anticoagulants It has several advantages over other methods in that it is easier to control, does not require routine laboratory studies and is not associated with an increased incidence of wound haematoma The main disadvantage is that the injection may on occasions be uncomfortable

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thromboses in the 83 anticoagulated patients and 22 (26 5 per cent) venous thromboses in their control group There was one pulmonary embolus (1 2 per cent) in the anticoagulated and eight (9 6 per cent) in the control group However, they found that anticoagulation was associated with an increase in the wound haematoma rate There were 29 wound haematomata (34 9 per cent) in the anticoagulated group compared with 20 (24 per cent) in the control group

In addition to the increased risk of wound haematoma formation, the level of anticoagulation may be difficult to regulate There is no standard dose, different patients react differently to the same dose and the same patient may react differently on a different occasion Hypnotics, particularly barbiturates, tend to interfere with their action In a retrospective study Muckle et al (1974) found that anticoagulation reached therapeutic levels in only 169 (65 per cent) of 260 patients The anticoagulation was inadequate in 79 and excessive in 12 patients When it was inadequate, it did not diminish the incidence of deep vein thrombosis or pulmonary embolism and when excessive was associated with a marked increase in the incidence of wound haematoma formation Daily estimation of the prothrombin time is essential until control is established and this requires adequate laboratory back up facilities

Low dosage heparin prophylaxis, introduced by Sharnoff & De Blasio in 1970, seems to overcome some of the disadvantages associated with other methods The results obtained in a variety of trials indicate that it is a useful method of diminishing the incidence of deep vein thrombosis (Kakker et al 1971, Williams 1971 and Gordon Smith et al 1972) In 1973 Sharnoff stated that he had had only two failures, confirmed at autopsy, compared with more than 1,450 successfully heparinized patients Interestingly, both failures occurred in elderly patients with a fracture of their proximal femur

Patients who sustain intertrochanteric and transcervical femoral fractures tend to be immobile from the time of injury whereas patients who undergo major elective surgery are mobile until the time of operation We decided, therefore, to start our heparin regimen on admission and not to wait until the patient had undergone surgery This was not associated with any excess bleeding during the operation nor with an increased wound haematoma or infection rate The results of our study indicate that when heparin is started at this time there is a marked decrease in the incidence of deep vein thrombosis This is not surprising as one of the main predisposing causes of deep vein thrombosis is immobility

One of the surprising findings in our study was that the incidence was higher in the 60–74 age group than in the over 75 year age group Previous work had suggested that the incidence increases with increasing age (Sevitt & Gallagher 1961) Another interesting finding is that the incidence was higher in patients undergoing nail and plate fixation compared with those undergoing nail fixation of their fracture

In our study sodium heparin (BP) was used, and the results indicate that it is as effective as the more expensive slow release calcium heparin

Van Vroonhoven (1974), in a controlled clinical trial using I^{125} labelled fibrinogen, found that low dosage subcutaneous heparin was more effective in preventing postoperative deep vein thrombosis than routine oral anticoagulation There was one (2 per cent) deep vein thrombosis in the 50 patients treated with heparin and nine (18 per cent) in the 50 patients who were anticoagulated

Gallus et al (1973) used a modified low dosage heparin regimen consisting of 5,000 units given thrice rather than

Acta orthop scand 47 283 289, 1976

PERIPHERAL NERVE REPAIRS BY THE FUNICULAR SUTURE TECHNIQUE

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Sixty one peripheral nerve repairs in 48 patients sutured by the funicular suture technique were followed up for a minimum of 2 years after operation the average follow up period being 48 months Useful recovery was obtained in 100 per cent of cases with radial and musculocutaneous nerve repairs Seventy five per cent of cases with median 82 per cent with ulnar and 88 per cent with digital nerve lesions attained the useful grade of recovery In the lower extremity, the motor recovery was excellent whereas the sensory recovery was poor In two out of three cases where cable grafting was performed between important funiculi the result obtained was excellent To obtain satisfactory neurological recovery the funicular suture technique using the surgical microscope is the method of choice for primary and secondary nerve suture and cable grafting

Key words microsurgery peripheral nerves, funicular suture technique

Accepted 6 i 76

The epineurial nerve suture has been used as the routine method for repairing severed nerves The functional recovery, however, has not been entirely satisfactory Malalignment of the funicular patterns at the suture surfaces is believed to be the main factor causing poor recovery (Edshage 1964, Bora 1967, Goto 1967 Hakstian 1968) To achieve their accurate approximation, Langley & Hashimoto 1917 and Sunderland (1953) advocated the funicular suture technique from the anatomical standpoint It was the experimental work of Ito & Ishikawa in 1964 which first indicated that nerve repair by the funicular suture technique was feasible in clinical practice and gave excellent results Since that time, we have employed this method of nerve repair using microsurgical techniques

The purpose of this paper is to present the follow-up results of nerve repairs sutured by this method

MATERIAL AND METHODS

Patients

Ninety injured nerves in 70 patients were repaired by the funicular suture technique The details are given in Tables 1 and 2 The ages of the patients ranged from 2 to 68 years Of the 70 patients 48 (61 nerves) were followed up for a minimum of 2 years The average follow up period was 48 months Three cases of cable grafting were included in this series

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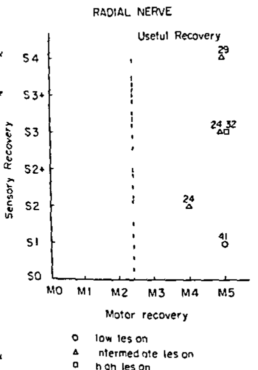


Figure 2 Follow-up result of radial nerve repairs Numbers adjacent to symbols indicate the period of follow-up in months

important that the epineurium and the perineurium are the only tissues to be pierced by suturing

In large nerve trunks containing many funiculi the functionally important funiculi particularly those situated at the marginal region of the cut surface were opposed

Cable grafting was performed when the surgical gap could not be overcome by either mobilization and/or transposition of the nerve or joint flexion of less than 90° in the elbow The grafting was carried out between important funiculi located with the aid of the intraneural topographic atlases

Evaluation

The degrees of motor and sensory recovery in each nerve of the upper extremity were assessed by the criteria described by Sakellarides (1962) a system in which the recovery is classified from M0 to M5 for the motor function and from S0 to S4 for sensory function The classification useful for recovery of hand function was assigned according to Zachary's method (1954)

In sciatic and peroneal nerve lesions the recovery was evaluated on the grading system reported by Clawson & Seddon (1960)

Each nerve lesion was divided into three categories high, intermediate and low

FOLLOW-UP RESULTS

All the five cases of radial nerve repairs which were followed up for a minimum of 2 years recovered almost normal motor function as is seen in Figure 2 Six out of eight cases of median nerve repairs obtained useful recovery of function (Figure 3) It is emphasized that two out of the three high lesions of the median nerve were within the range of useful recovery and the remaining case could be judged as almost useful because its recovery was classified as M2 and S2+ Out of 17 ulnar nerve repairs, 14 attained useful recovery of function, while the remaining three were near this level of recovery (Figure 4) In patients with combined median and ulnar nerve lesions, one out of three attained a satisfactory degree of recovery Two musculo

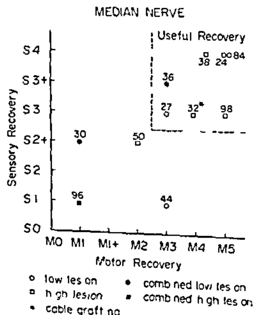


Figure 3 Follow up result of median nerve repairs

Table 1 Survey of nerves sutured and followed up

Nerve	No of nerves repaired	No of nerves followed up
Radial	9	5
Median	21	11
Ulnar	35	20
Musculocutaneous	2	2
Digital	16	16
Tibial	2	2
Peroneal	5	5
Total	90	61

Table 2 Details of injured nerves

		Patients
Primary suture		3
Secondary suture		67
Within 1 month	6	
Within 3 months	26	
Within 6 months	19	
Within 1 year	12	
Over 1 year	4	
Single nerve lesion		52
Two nerve lesions		16
Three nerve lesions		2
Total		70

Surgical technique

The funicular suture was performed as follows Under the surgical microscope preparatory trimming of the severed nerve ends was carefully carried out, using a razor blade as far as the unscarred level of the nerve trunk at which point the funiculi were caused to project from the cut surface Then the funicular pattern at the cut end was sketched on paper This sketch is useful for the orientation and identification of funiculi to be sutured Sunderland (1945, 1972) has already published precise maps of funicular patterns of the main nerves Tamura (1969) and Urushidani (1974) in our department have also described the intraneural topographic atlases of the main nerves in the upper and lower extremities for clinical application In addition to the position shape and size of the funiculi these maps assist in locating the functionally important funiculi and in identifying the corresponding funiculi to be approximated

After the funicular identification both nerve ends were secured with two epineurial sutures about 180 degrees apart approximating the nerve ends without distorsion or twisting A fine silk suture of 8 0 with an atraumatic needle was passed through the epineurium and then the perineurium of the funiculus to be sutured The same procedure was performed on the opposite stump in a figure-0 or figure-8 as shown in Figure 1 A complete circumferential repair usually required a total of six to ten stitches for a satisfactory alignment of both funicular ends Throughout the procedure it is

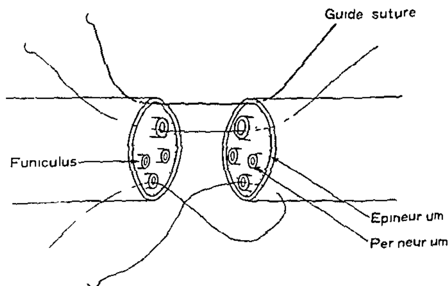


Figure 1 Schematic representation of the funicular suture technique employed by us

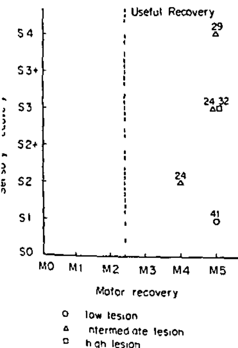


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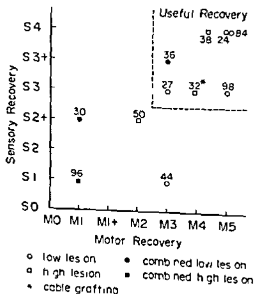


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Peroneal	5	5
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		Patients
Primary suture		3
Secondary suture		67
Within 1 month	6	
Within 3 months	26	
Within 6 months	19	
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Single nerve lesion		52
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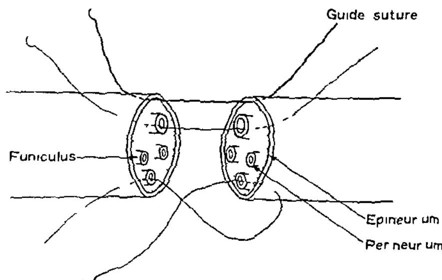


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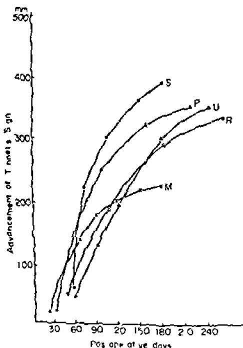


Figure 5 Advancement of Tinel's sign in repaired nerves R radial nerve M median nerve U ulnar nerve P peroneal nerve S sciatic nerve

electrophysiological studies conducted by Ishikawa (1966), Goto (1967) and Yamamoto (1974) in our department (Figure 6)

The funicular pattern within a nerve only remains constant for a maximum of 15 millimeters because of the plexus formation of the funiculi (Sunderland 1970) Thus, a discrepancy in the funicular pattern may be inevitable in the approximating surfaces However, the orientation and identification of the funiculi to be sutured are not always difficult in practice, since certain funiculi with important functions have particular localizations in the cross sections at certain levels of a nerve trunk (Tamura 1969, Urushidani 1974) In addition, all the funiculi are not simultaneously involved in plexus formation at the same level (Sunderland 1970) Thus a successful connection can be expected in at least some funicular groups even if the corresponding funiculi are not completely opposed Identification of funicular

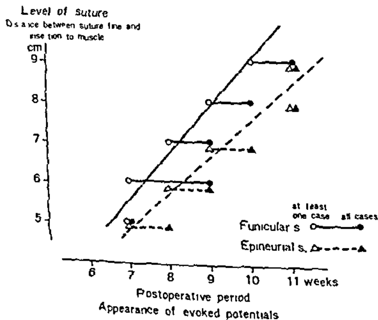


Figure 6 Appearance of evoked potentials after nerve suture in the peroneal nerves in dogs More rapid and more complete recovery of the function is observed in the funicular suture at each level of repair compared with the epineurial suture

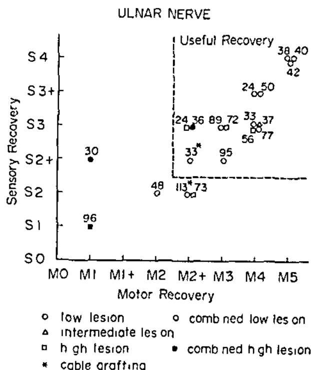


Figure 4 Follow-up result of ulnar nerve repairs

cutaneous nerve lesions showed an excellent return of function, evaluated by the same criteria All digital nerve sutures except two achieved satisfactory return of sensation, over S2+

In seven cases of nerve suture in the lower extremity, the sensory recovery was satisfactory in all cases The motor function, however, recovered to the grade "good" in only one out of five patients with sciatic nerve repair and one out of two with tibial nerve repair

Table 3 gives the details of the three cases of cable grafting, of whom two achieved useful recovery of hand function

DISCUSSION

The follow-up study revealed that the funicular suture technique was able to bring about a satisfactory recovery of function in the repaired nerves 'Useful recovery was enjoyed by 100 per cent of patients with radial and musculocutaneous nerve lesions In median, ulnar and digital nerve lesions, 75 per cent, 82 per cent and 88 per cent of repaired cases respectively, attained useful recovery, the remainder demonstrating a function close to the 'useful' grade

The results obtained in this series appear to be better than those obtained by the traditional suture method (Nicholas & Seddon 1957, Larsen & Posch 1958 Sakellarides 1962, Seddon 1972) The results indicated that the more simple the funicular pattern the better the recovery It is also possible that nerve repairs of low level and/or single lesions achieved better results than those of high level and/or combined lesions

The funicular suture technique improved not only the quantity but also the quality of the nerve regeneration A reduced initial delay, an increased rate of axon growth and a rapid return of function were observed in nerves repaired by this technique Figure 5 depicts the advancement of Tinel's sign in representative cases

Bora (1967), Hakstian (1968) and Grabb et al (1970) have reported the superiority of the funicular suture over the epineurial suture The same conclusion was confirmed by histological and

Table 3 Cable grafting

Case no	Age	Sex	Nerve	Level	Surgical gap (cm)	Follow-up period (months)	Result
1	25	female	Median	Elbow	12	32	M4 S3
2	42	female	Ulnar	Wrist	3	113	M2+, S2
3	17	male	Ulnar	Forearm	12	33	M2+, S2+

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function by electrical stimulation (Hakstian 1968, Vandeput et al 1969, Grabb et al 1970) is presumably ideal but is time consuming and restricted, in practice, to the primary suture

The less satisfactory result following peroneal nerve sutures is considered to be caused by the peculiarity of the funicular pattern at the level of the fibular head, where the funiculi are composed of intermingled motor and sensory axons (Urushidani 1974) This is also true in nerve lesions at a high level The poor result in combined lesions may result from associated extensive damage to soft tissue and blood vessels

The surgical gaps could usually be closed without pronounced tension No significant difference in the follow up results was found between various closure distances, although the number of cases appears to be too limited to draw such a definite conclusion as did Millesi et al (1972 a, b)

Conclusion

From the results of clinical and experimental investigations, it is concluded that the funicular suture technique using the surgical microscope is the method of choice for peripheral nerve repair It is stated that primary suture and nerve grafting are the absolute indications for the application of this microsurgical technique Even in secondary nerve suture, repairs by the funicular suture technique also achieved an excellent recovery of the nerve function when compared with the results of epineurial suture

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Acta orthop scand 47, 290–298, 1976

CHANGES IN ^{35}S-SULPHATE UPTAKE IN DIFFERENT TISSUES IN THE KNEE AND HIP REGIONS OF RABBITS DURING IMMOBILIZATION, REMOBILIZATION AND THE DEVELOPMENT OF OSTEOARTHRITIS

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In order to observe phenomena accompanying the development of osteoarthritis of the rabbit knee consistently appearing within 4-6 weeks as a consequence of immobilization of this joint studies on ^{35}S sulphate ($Na_2{}^{35}SO_4$) uptake were carried out The investigation suggests that immobilization of the knee leads within 2 4 weeks to increased sulphate uptake in bone cartilage and ligaments in the knee region and in the hip (not immobilized) of the same leg The first marked changes in ^{35}S sulphate uptake were found in the ligaments and the articular cartilage as early as after 4 days of immobilization

Key words osteoarthritis, radioactive sulphate, immobilization knee hip articular cartilage

Accepted 9 ii 76

In order to find an experimental model of osteoarthritis on which studies concerning pathogenesis and therapy could be based, a series of experiments were carried out with 260 adult rabbits, using immobilization of the knee as the factor provoking degenerative changes in this joint (Langenskiold et al 1975)

It has been shown by other authors that long-term immobilization may cause degenerative changes in joints (Evans et al 1960, Salter & Field 1960, Trias 1961, Hall 1963 a, b, Thaxter et al 1965, Salter 1967, Thompson & Bassett 1970, Moskowitz 1972) In our own series of experiments it was demonstrated that immobilization of the knee consistently resulted in osteoarthritis of this joint when the immobilization period exceeded 3 weeks The degenerative changes were demonstrated by radiography and histological examination (Figure 6 c and d) However, it was desirable to detect, by more sensitive methods, the reactions of the joint and the surrounding tissues to immobilization and subsequent remobilization Determination of the ^{35}S-sulphate uptake of different tissues of the knee region in the immobilized limb and a comparison with the sulphate incorporation of the corresponding tissues in the contralateral leg was considered a means of demonstrating early reactions to immobilization It could be expected that

changes in 35S-sulphate uptake would appear before changes demonstrable in radiographs and histological sections

METHODS

With the aid of 35S sulphate an idea can be obtained of the formation of connective tissue (Amprino 1955) In particular the glycosaminoglycan synthesis of chondrocytes and fibroblasts has been studied by means of 35S sulphate (Dziewiatkowski 1951 Belanger 1954 Mancini et al 1961 Crane 1962 Maroudas 1975)

Within 1 2 hours of the administration of 35S sulphate to test animals the label can be demonstrated within the cell as was shown by Picard et al (1964) Furthermore it has been shown that the maximum specific activity of labelled chondroitin sulphate is reached within 24 hours after isotope administration One to two days after injection of 35S sulphate radioactivity can be traced in the cells and the extracellular matrix Six to seven days after the injection of the label the radioactivity is located almost exclusively in the organic matrix (Belanger 1954 Dziewiatkowski 1949)

In the series of experiments described in this article the knees of adult rabbits aged more than 9 months were immobilized in extension by means of a plastic splint or by bandaging the knee region with Tensoplast® The hip remained free and movable This method of immobilization has previously been described (Michelsson & Langenskiold 1972 b Michelsson & Langenskiöld 1974)

The 35S sulphate uptake in ligaments cartilage and bone in the knee and hip regions was studied by two methods by scintillation counting and by autoradiography

In the series studied by scintillation counting every animal was given 1 mCi 35S sulphate (carrier free The Radiochemical Centre Amersham) intramuscularly in the scapular region 24 hours before being killed Samples were taken from both hind limbs from the cartilage of the head of the femur the joint capsule of the hip the cortical and the spongy bone of the femoral diaphysis the proximal articular cartilage of the tibia the medial collateral ligament of the knee the medial meniscus and the spongy bone of the proximal metaphysis of the tibia The samples of soft tissues were taken with a knife and the bone samples with a revolving saw (Figure 1)

The samples were dried weighed wet-combusted and precipitated in the form of barium sulphate ad modum Moltke 1957) The precipitate was then mixed in scintillation gel and the radioactivity was determined with a liquid scintillation counter The measured radioactivities (cpm/mg dry tissue) were tested using analysis of variance (two factor design) In order to scale the raw data to a common arbitrary level the radioactivities measured for each tissue in the control limb not immobilized were given the value 100

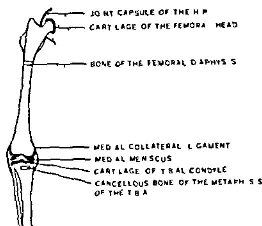


Figure 1 The origin of the samples for investigation

In the series studied by autoradiography each rabbit was given 2 5 mCi 35S sulphate intra abdominally and one day after the injection the animals were killed After fixation in formalin and decalcification histological sections were made The autoradiograms were made using dental X ray film (the technique has been published earlier by Langenskiöld et al. 1967) The film was exposed for 6–8 weeks and developed in the usual way The histological sections were dyed using Alcian blue PAS

MATERIAL

The material consisted of three groups of animals In the first group consisting of 16 animals the knees were immobilized for periods varying from 1 to 130 days Eight of the rabbits were killed 1 day after injection of sulphate and removal of the immobilizing bandage and eight were killed before the bandage was removed Samples were taken for scintillation counting studies and prepared in the way described above

The second group consisted of six rabbits whose right knee was immobilized in the way described for 40 days after which the splint was removed and the limb remobilized The animals

were given injections of sulphate 1 day before killing and killed 4 to 30 days after removal of the immobilizing bandage

From the animals of the first and the second group a total of 337 tissue samples were studied for their ^{35}S sulphate content

The third group consisted of six rabbits, three of them had one knee immobilized for 2 weeks and three others for 4 to 6 weeks From these rabbits histological sections and autoradiograms were obtained in the manner described

RESULTS

The radioactivities in the various tissues of the immobilized and non-immobilized (control) limbs were compared, and the results are shown in Figures 2–7

Medial collateral ligament of the knee (Figures 2 and 3) In the immobilized limb the ^{35}S-sulphate uptake of the ligament had increased twofold within 4 days of immobilization This increase reached its peak value, more than four times the control value, after 1 month Then the uptake began to decrease gradually until, after an immobilization of four and a half months, it was only slightly above the control value

When the knee was remobilized after 40 days of immobilization the uptake was found to remain at the high level of more than three times the control value for at least 10 days

The autoradiograms showed a very powerful radioactivity in the right knee compared with the control limb in all ligaments adherent to the joint capsule (Figure 6 a and b)

Medial meniscus of the knee During immobilization and remobilization the ^{35}S sulphate uptake of the meniscus of the immobilized knee increased in a similar way to that of the ligaments but to a lesser degree (Figures 1, 2 and 3)

The proximal articular cartilage of the tibia The sulphate uptake of the articular cartilage of the tibia increased as early as 4 days after immobilization After 4 weeks it was increased about 50 per cent and remained at this level when immobilization was prolonged (Figures 2 and 3)

After 2 weeks of immobilization the articular cartilage usually disappeared in the weightbearing areas Therefore the results obtained after 60 and 135 days of immobilization are based on the cartilage which could be taken from the peripheral areas

In the autoradiograms the radioactivity was low in the central areas of the condyles but high in the peripheral osteophytes and in the cartilaginous islets in the bone tissue (Figure 6 a and b)

Tibial bone In the metaphyseal bone of the tibia of the immobilized limb the sulphate uptake increased but did so later and to a less marked degree than that of the ligaments After 3 months of immobilization the sulphate level decreased to below control values but because local structural changes develop in the metaphysis due to a prolonged period of immobilization, no absolute conclusions should be drawn from these results (Figures 2 and 3)

Joint capsule of the hip The sulphate uptake of the capsule of the hip joint had definitely increased in the immobilized limb after 4 days of immobilization Two months after application of the immobilizing bandage it was more than four times as high as the control level After four and a half months of immobilization the uptake was still twice as high as the control level During remobilization after 40 days of immobilization, the uptake was found to have increased to more than five times the control level After this there was an extremely sharp decrease for some days until the uptake stabilized at about twice the control level (Figures 4 and 5)

The autoradiograms showed the capsule of the right hip to be definitely more radioactive and thicker than the capsule on the other side (Figure 7)

Cartilage of the femoral head In the immobilized limb the sulphate uptake of

Figure 2 ^{35}S *sulphate uptake in different tissues of the knee after various periods of immobilization*

Figure 3 ^{35}S *sulphate uptake in different tissues of the knee after immobilization and subsequent remobilization*

Figure 4 ^{35}S *sulphate uptake in different tissues of the hip and in the femoral bone after various periods of immobilization*

Figure 5 ^{35}S *sulphate uptake in different tissues of the hip and in the femoral bone after immobilization and subsequent remobilization*

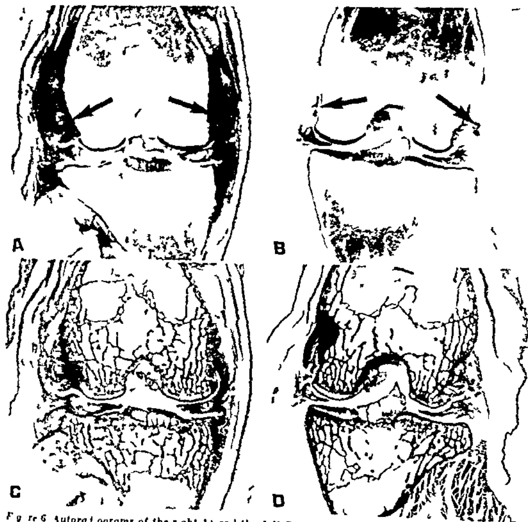


Figure 6 Autoradiograms of the right A) and the left B) knee of a

the cartilage had increased from the first day of immobilization and was twice the control level on the tenth day The uptake remained relatively stable being about 0 per cent higher than the control level through ut the longer periods of immobilization Figures 4 and 5)

From the autoradiograms the difference could not be seen equally clearly Figure 7)

Femoral bone The changes were very slight similar to those in the tibial bone (Figures 4 and 5) These samples contained periosteum cortical and spongy bone and bone marrow

Summarizing it can be said that in the tissues of the immobilized limb with the exception of the bone the uptake of 35S sulphate throughout the 130 day period of immobilization was higher than the control level In principle the same phenomena were visible in the autoradio-

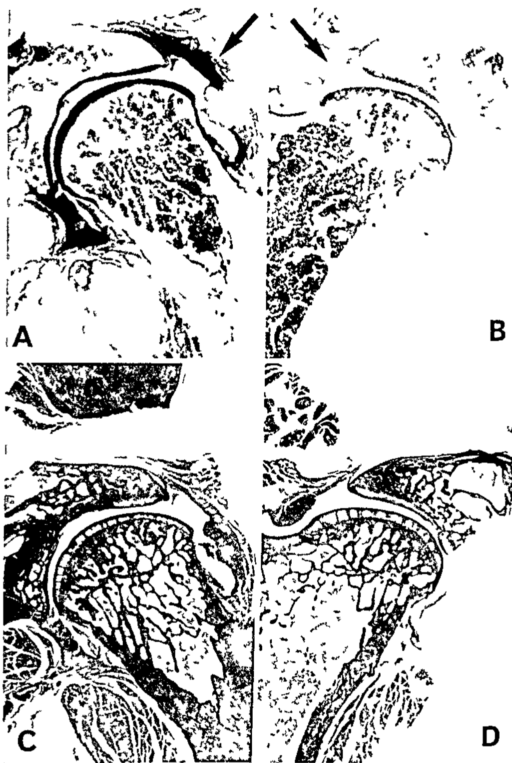


Figure 7 The right knee of an adult rabbit was immobilized in extension for 4 weeks Autoradiogram of the region of the right A) and the left B) hip and corresponding histological sections of the region C) and D) In the articular cartilage and the capsule the radioactivity is much greater in the region of the right hip than in the left The radioactivity is the same in the bone marrow of both legs

grams, but especially in the articular cartilage and meniscus the radioactivity varied extensively in the different regions During the remobilization phase the uptake in all tissues studied was higher than in the control tissues during the first 10 days after removal of the immobilizing bandage and remained that way even after some time, except in the bone and the articular cartilage of the femoral head The greatest differences in the ^{35}S-sulphate uptake of the various tissues of the immobilized and non immobilized limb were observed in the joint capsule of the hip, the medial collateral ligament of the knee and the medial meniscus

According to Wilcoxon's test, removal of the splint or bandage at the time of the sulphate injection 24 hours before killing, or at the time of the killing itself, significantly affected the uptake of ^{35}S-sulphate only in the tibial bone and the articular cartilage of the femoral head

The effects of both main variables time of immobilization and type of tissue studied, were statistically significant at a level of $P < 0.01$

DISCUSSION

On the basis of radiographs and histological and macroscopic studies degenerative changes were observed in the knee and hip of the immobilized limbs even after only 10 days of immobilization (Langenskiold et al 1975) The capsule of both the knee and the hip joint was consistently found to be thickened A similar thickening of the joint capsule is also a regular feature of human osteoarthritis (Lloyd Roberts 1953) The severity of the degenerative changes in the joints of the animals was directly correlated with the length of the immobilization period

The experiments with ^{35}S sulphate showed as was expected, that the sulphate uptake in the joint regions of an immobilized limb is modified at a stage when no histological or radiological changes can yet be demonstrated Immobilization and remobilization both distinctly increased the ^{35}S-sulphate uptake in the tissues of the immobilized limb The first marked changes in sulphate uptake were found, in the ligaments and the articular cartilage, as early as after 4 days of immobilization According to the autoradiograms and the histological examination thickening was induced in ligaments, joint capsules and menisci, from which it can be concluded that an increased ^{35}S-sulphate uptake cannot result from, e g , decreased amount of protein or collagen

The findings speak in favour of the idea that changes in the soft tissues around osteoarthritic joints play a role in the pathogenesis of *osteoarthritis*

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Acta orthop scand 47, 299-303, 1976

CORRECTION WITH GROWTH FOLLOWING DIAPHYSEAL FOREARM FRACTURE

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In 25 children with fracture of the shafts of the forearm an average angulation deformity of 20° was recorded when the fracture had healed At follow-up which took place after the cessation of growth, the angulation deformity was reduced by half, there was, however a large individual variation Both severe and less severe deformities were found to be corrected Correction was more likely in younger children than in older children, though again there were exceptions to this rule The most common dysfunction recorded was a decreased pronation supination This was not very closely correlated with angular deformity

Key words forearm fracture, deformity, diaphysis, growth

Accepted 16 i 76

Unlike adults, children are supposed to be able to achieve correction of post-fracture angulation deformity of the forearm (Aitken 1935, Blount et al 1942 and others) In the Department of Orthopaedic Surgery in Malmö the policy has been to reduce diaphyseal fractures of the forearm in children to an anatomically correct position Nevertheless in some instances the treatment has not been successful

The purpose of this investigation was to evaluate the late results in incompletely reduced forearm fractures in children and to study the relationship to age and degree of deformity

Financial support was obtained from the Swedish Medical Research Council (project no B 75-17X 2737-07C)

MATERIAL AND METHODS

All shaft fractures of the forearm in children treated in Malmo since 1950 were available for the study From almost 200 treated cases, 25 were selected in whom there had been a discernible angular deformity at the time of the termination of treatment From the films of these cases it was found that only a malpositioning amounting to 10° or more could be recognized The 25 patients therefore had an *early residual angulation* of at least 10° measured as the maximum angulation in either the AP or the lateral film of the forearm after the fracture had healed In many instances the position of the fragments had been anatomically correct after the reduction but had deteriorated later on The 25 cases also fulfilled the criterion that they, at the time of follow up should have obtained the maximum correction possible at the cessation of growth The age of the children varied between 2 and 15 years at the time of the fracture

The follow up examination included radiograms of both forearms Maximum angulation of the radius or the ulna was measured on AP

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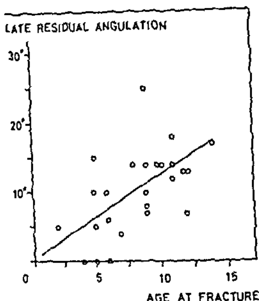


Figure 3 The relationship between the age at the time of fracture and late residual angulation

residual angulation had been greater in the radius or the ulna and there was no significant correlation between early residual angulation and late residual angulation Obviously a child with a severe deformity has on average the same chance to achieve correction of the angulation spontaneously as a child with a less severe angulation (Figure 1) In spite of the large variation there was a significant correlation between the late residual angulation and the limitation of pronation and supination (Figure 2) The age at the time of the fracture was correlated positively with late residual angulation older children being less able to compensate for the fracture deformity Figure 3) Also there was a slight but significant correlation between the age at fracture and the reduction of residual angulation which had taken place between the time of the termination of the treatment and the time of follow up Figure 4)

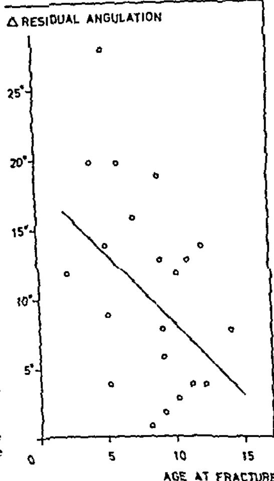


Figure 4 The relationship between the age at the time of fracture and the reduction in the residual angulation

DISCUSSION

The capacity for spontaneous correction of deformity has been demonstrated to be greatest in the distal metaphyseal part of the radius and the ulna (Blount 1954 Hughstone 1962 Lindholm *et al* 1972 Koncz 1973) Moreover, *Hughstone* (1962) claims that in diaphyseal fractures "growth will not correct angulation deformity as it does in metaphyseal fractures and on the whole opinions as to whether or not diaphyseal fracture deformity can spontaneously achieve correction differ a great deal (Gandhi et

and lateral films and a comparison was made between the injured and the uninjured forearm Although the angulation in most instances was rounded and did not have a sudden transition it was possible by comparing the two sides to evaluate the differences Deviation from the shape of the normal side was recorded and is referred to as *late residual angulation*

Finally the pronation supination range was measured by asking the patient to turn a handle with his elbow locked

Standard statistical procedures were applied Probability levels better than 95 per cent are referred to as significant

RESULTS

It could be demonstrated that at follow-up the children had achieved reduction of their early residual angulation by an average of 10° or about 50 per cent (Table 1) The pronation and supination range was decreased by an average of 25° which is about one fifth of the normal range of movement (Table 1) The late residual angulation did not depend on the localization of the fracture, however, most of the fractures were in the middle third of the diaphysis and the number does not permit positive conclusions Fractures in the distal third of the shafts of the radius and the ulna had rarely been left with any discernible early residual angulation There was no difference between cases in whom the early

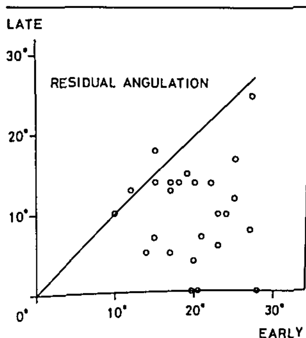


Figure 1 The relationship between early and late residual angulations

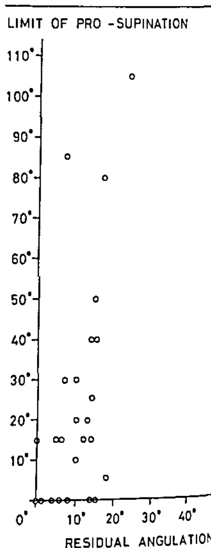


Figure 2 The relationship between late residual angulation and the limitation of pronation supination

Table 1 Age and variables of deformity

Number	25	
Age at fracture	8 4 ± 3 1	(2 15)
Residual angulation (late)	10 2 ± 6 1	
Residual angulation (early)	19 8 ± 5 0	
Limitation of pronation supination	24 6 ± 28 f	

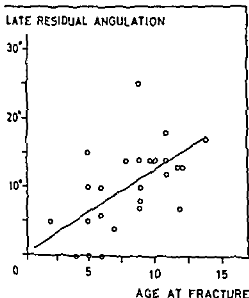


Figure 3 The relationship between the age at the time of fracture and late residual angulation

residual angulation had been greater in the radius or the ulna and there was no significant correlation between early residual angulation and late residual angulation Obviously a child with a severe deformity has, on average, the same chance to achieve correction of the angulation spontaneously as a child with a less severe angulation (Figure 1) In spite of the large variation there was a significant correlation between the late residual angulation and the limitation of pronation and supination (Figure 2) The age at the time of the fracture was correlated positively with late residual angulation, older children being less able to compensate for the fracture deformity (*Figure 3*) Also, there was a slight but significant correlation between the age at fracture and the reduction of residual angulation which had taken place between the time of the termination of the treatment and the time of follow-up (Figure 4)



Figure 4 The relationship between the age at the time of fracture and the reduction in the residual angulation

DISCUSSION

The capacity for spontaneous correction of deformity has been demonstrated to be greatest in the distal *metaphyseal* part of the radius and the ulna (Blount 1954, Hughstone 1962, *Lindholm et al* 1972, Koncz 1973) Moreover, Hughstone (1962) claims that in *diaphyseal fractures* "growth will not correct angulation deformity as it does in metaphyseal fractures" and on the whole opinions as to whether or not diaphyseal fracture deformity can spontaneously *achieve* correction differ a great deal (Gandhi et

al 1962) Koncz (1973) observed that a spontaneous correction could occur in the distal third of the diaphyses whereas the curvature remained if the fracture was located more proximally

It should be emphasized that in the present study only the angular deformity was recorded This may explain, to some extent, the large residual variance of the data In the past, some authors have suggested that an angular deformity of 10° or even 20° may be left untreated in children (Steinart 1966, Ehalt 1961) This statement cannot be verified from our findings in that we have seen deformities of that magnitude which have not corrected with growth In fact, the degree of deformity seems to be unrelated to the final result, small angulation deformities may remain and large deformities may achieve correction Moesner & Østergaard (1966) suggest that children under 9 years of age are able to achieve correction of 90 per cent of the deformity So far, in our study, *only children under 10 have been able to* produce large corrections with growth However, in our series one patient who sustained a fracture at the age of 9 still had, at the age of 19, a 25° deformity and a locked pronation and supination Therefore this '9 years' rule is probably not valid in all instances and large angulation deformities can probably be left untreated only in very young children Nevertheless, it is possible to demonstrate a significant relationship between age and the ability to correct deformity as has been suggested previously by Blount (1954), Buck et al (1966) and Moesner & Østergaard (1966), but the residual variance involved in this relationship is so large that conclusions and predictions cannot easily be made for the individual case

Locked or very limited pronation and supination was seen in a few cases A 19 year old woman with very poor range of pronation and supination motion suffered more from the cosmetic deformity of the forearm than from the limited range of movement, and some patients with a limitation of 60° or less in the range of pronation and supination seemed to be unaware of their incapacity

The conclusion from our findings must be that all deformities exceeding 10 should be corrected (at least those in the middle third of the shafts of the radius and the ulna) if one wants to ensure a final result with a correct anatomical position Even if a young child has a good chance of achieving correction of an angular deformity the ability to correct is not possible to predict in the individual case Smaller or greater angulations within limits, have the same chance of returning to normal The correlation between the final angulation deformity and the range of pronation and supination motion is rather weak, probably this type of movement is influenced by other factors as well

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Acta orthop scand 47, 304–307, 1976

POSTERIOR INTEROSSEOUS NERVE PARALYSIS CAUSED BY FIBROUS BAND COMPRESSION AT THE SUPINATOR MUSCLE

A Report of Four Cases

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Four cases are reported of paralysis of the posterior interosseous nerve caused by compression of the nerve between the Arcade of Frohse and the two heads of the supinator muscle All four cases were treated by decompression with excellent results

Key words nerve compression, posterior interosseous nerve

Accepted 24 ii 76

Isolated weakness of the muscles innervated by the posterior interosseous nerve (PIN) is rare (Mulholland 1966, Goldman et al 1969, Barton 1973) Clinically, the patient is unable to extend the fingers at the metacarpophalangeal joints, the wrist can dorsiflex, but does so in a dorso-radial direction, since there is normal function of the extensor carpi radialis longus muscles, but weakness of the extensor carpi ulnaris muscles There is no sensory deficit (Spinner & Spencer 1974)

CASE REPORTS

Case 1 A 20 year old woman Five years previously the patient had been examined and treated for weakness of the right serratus anterior muscle The present examination showed no sequelae

Over a period of 2 months there had been progressive drop fingers in the left hand at first with pain around the elbow which had now disappeared There was no history of trauma apart from the stress of repeated pronation and supination movements in connection with her performance as a go go dancer General physical examination showed weakness or complete paralysis of the muscles innervated by the PIN There were no other pathological findings or any sensory deficit, and a roentgenogram of the left elbow was normal

At operation the PIN was found to be thickened proximal to its entrapment at the supinator muscle A fibrous band was found at the entrance to the muscle, which was otherwise normal The band was divided There were no postoperative complications The patient had progressive return of function, and 5 months after operation there was only slight weakness of the abductor pollicis longus muscle and of the extensor to the index finger Six years later the findings were quite normal

Case 2 A 23 year old woman who was employed as a clerk With no known history of trauma the patient developed pain around the lateral aspect of the left elbow and on examination 14 days later there was weakness of extension of the wrist and fingers She was seen 4 months later and there was now weakness or complete paralysis of the muscles innervated by the PIN There was no sensibility deficit Roentgenograms of the left elbow were normal

At operation the PIN was found to be compressed at the entrance to the supinator muscle Proximal in the muscle there was a tight fibrous band but the muscle was otherwise normal The fibrous band was divided There were no

postoperative complications Four months later findings were completely normal, as was the case on examination 3 years later

Case 3 A 53 year old labourer who previously suffered from renal colic, but was otherwise healthy He had sustained minor injuries to the left arm and elbow, probably acquired while inebriated With no obvious history of trauma the patient was suddenly unable to extend the fingers On examination 6 weeks later there was paralysis of the muscles innervated by the PIN There was normal function of the muscles innervated by the radial nerve There was no sensory deficit Roentgenogram of the elbow was normal

Operation revealed two fibrous arched bands at the point of entry of the nerve into the supinator muscle and on pronation it was clear that the nerve was compressed at this point The muscle was otherwise normal The nerve was decompressed by cutting the fibrous band Postoperatively there were no complications On examination 1 year later there was only moderate weakness when the patient tried to extend the middle finger otherwise no weakness was found

Case 4 A 61 year-old lumberjack, previously healthy One and a half years previously the patient experienced minor trauma to the right elbow with pain in the fingers disappearing in the course of 2 to 3 weeks *Six months later the* patient was suddenly unable to extend the three ulnar fingers On examination in the department complete paralysis of the muscles innervated by the PIN was found but there was no sensory deficit Roentgenogram of the elbow was normal

On operation the nerve was found to be compressed at the entrance to the supinator muscle where there was a fibrous band between the two heads of the muscle. The band was divided Postoperatively there were no complications

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DISCUSSION

Peripheral paralysis of the radial nerve is most often traumatic in origin (Barton 1973) Where there is no history of trauma the cause is often compression by a tumour (Capener 1966, Bowen & Stone 1966, Sharrard 1966, Richmond 1973)

Compression not caused by a tumour is reported to be caused by an accessory lateral head of the triceps muscle (Lotem et al 1971) In rheumatoid arthritis which involves the elbow there is a risk of compression of the PIN (Popelka & Vainio 1974) In resistant cases of tennis elbow Roles & Maudsley (1972) found, in 36 cases, that the radial nerve may be

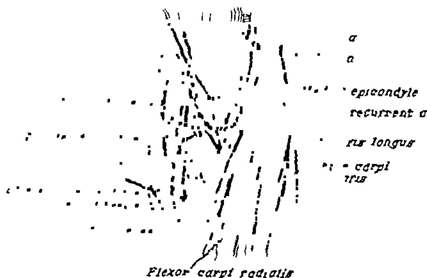


Figure 1 Shows the areole of Frohse between the two heads of the supinator muscle where the posterior interosseous nerve can be compressed (after Spinner 1968)

Acta orthop scand 47, 304-307, 1976

POSTERIOR INTEROSSEOUS NERVE PARALYSIS CAUSED BY FIBROUS BAND COMPRESSION AT THE SUPINATOR MUSCLE

A Report of Four Cases

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Four cases are reported of paralysis of the posterior interosseous nerve caused by compression of the nerve between the Arcade of Frohse and the two heads of the supinator muscle All four cases were treated by decompression with excellent results

Key words nerve compression, posterior interosseous nerve

Accepted 24 ii 76

Isolated weakness of the muscles innervated by the posterior interosseous nerve (PIN) is rare (Mulholland 1966, Goldman et al 1969, Barton 1973) Clinically, the patient is unable to extend the fingers at the metacarpophalangeal joints, the wrist can dorsiflex, but does so in a dorso-radial direction, since there is normal function of the extensor carpi radialis longus muscles, but weakness of the extensor carpi ulnaris muscles There is no sensory deficit (Spinner & Spencer 1974)

CASE REPORTS

Case 1 A 20 year old woman Five years previously the patient had been examined and treated for weakness of the right serratus anterior muscle The present examination showed no sequelae

Over a period of 2 months there had been progressive drop fingers in the left hand at first with pain around the elbow which had now disappeared There was no history of trauma apart from the stress of repeated pronation and supination movements in connection with her performance as a go go dancer General physical examination showed weakness or complete paralysis of the muscles innervated by the PIN There were no other pathological findings or any sensory deficit, and a roentgenogram of the left elbow was normal

At operation the PIN was found to be thickened proximal to its entrapment at the supinator muscle A fibrous band was found at the entrance to the muscle, which was otherwise normal The band was divided There were no postoperative complications The patient had progressive return of function and 5 months after operation there was only slight weakness of the abductor pollicis longus muscle and of the extensor to the index finger Six years later the findings were quite normal

Case 2 A 23 year old woman who was employed as a clerk With no known history of trauma the patient developed pain around the lateral aspect of the left elbow, and on examination 14 days later there was weakness of extension of the wrist and fingers She was seen 4 months later and there was now weakness or complete paralysis of the muscles innervated by the PIN There was no sensibility deficit Roentgenograms of the left elbow were normal

At operation the PIN was found to be compressed at the entrance to the supinator muscle Proximal in the muscle there was a tight fibrous band but the muscle was otherwise normal The fibrous band was divided There were no

postoperative complications. Four months later findings were completely normal, as was the case on examination 3 years later.

Case 3 A 53 year old labourer who previously suffered from renal colic, but was otherwise healthy. He had sustained minor injuries to the left arm and elbow, probably acquired while inebriated. With no obvious history of trauma the patient was suddenly unable to extend the fingers. On examination 6 weeks later there was paralysis of the muscles innervated by the PIN. There was normal function of the muscles innervated by the radial nerve. There was no sensory deficit. Roentgenogram of the elbow was normal.

Operation revealed two fibrous arched bands at the point of entry of the nerve into the supinator muscle, and on pronation it was clear that the nerve was compressed at this point. The muscle was otherwise normal. The nerve was decompressed by cutting the fibrous band. Postoperatively there were no complications. On examination 1 year later there was only moderate weakness when the patient tried to extend the middle finger, otherwise no weakness was found.

Case 4 A 61-year-old lumberjack, previously healthy. One and a half years previously the patient experienced minor trauma to the right elbow with pain in the fingers, disappearing in the course of 2 to 3 weeks. Six months later the patient was suddenly unable to extend the three ulnar fingers. On examination in the department complete paralysis of the muscles innervated by the PIN was found but there was no sensory deficit. Roentgenogram of the elbow was normal.

On operation the nerve was found to be compressed at the entrance to the supinator muscle, where there was a fibrous band between the two heads of the muscle. The band was divided. Postoperatively there were no complications.

When seen 3 months later findings were quite normal. Five years later there was still normal function of the PIN.

DISCUSSION

Peripheral paralysis of the radial nerve is most often traumatic in origin (Barton 1973). Where there is no history of trauma the cause is often compression by a tumour (Capener 1966, Bowen & Stone 1966, Sharrard 1966, Richmond 1973).

Compression not caused by a tumour is reported to be caused by an accessory lateral head of the triceps muscle (Lotem et al 1971). In rheumatoid arthritis which involves the elbow there is a risk of compression of the PIN (Popelka & Vainio 1974). In resistant cases of tennis elbow Roles & Maudsley (1972) found, in 36 cases, that the radial nerve may be

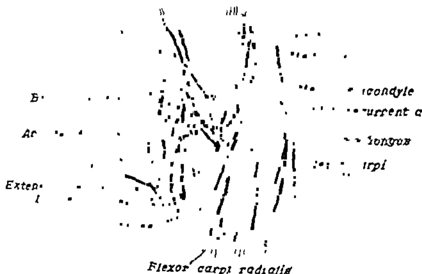


Figure 1 Shows the arcade of *Frohse between the two heads of the supinator muscle, where the posterior interosseous nerve can be compressed (after Spinner 1968)*

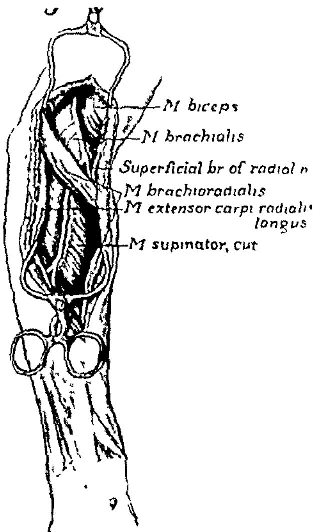


Figure 2 Shows the course through the supinator muscle of the posterior interosseous nerve, after an antero-lateral incision and free dissection (after Mayer & Mayfield 1947)

compressed in its course from the elbow and down to the supinator muscle by adhesions to the tissues overlying the radial head, by a more medially situated origin of the extensor carpi radialis brevis muscle than is usually described, or by a fibrous edge in the superficial layer of the supinator muscle

Spinner (1968) reported one case which like our four cases was caused by compression of the nerve at the entrance to the supinator muscle, between the two heads of the muscle and the fibrous band lying between them (the Arcade of Frohse) (Figure 1) If there is severe narrowing here the nerve may be compressed, especially with continued pronation and supination movements

In cases with a sudden development of paralysis of the PIN, like our cases 3 and 4, one must first think of causes such as "Saturday evening palsy" or previous injection around the lateral epicondyle of the humerus

It is agreed that in PIN paralysis of unknown cause, surgical exploration is indicated, since the nerve may be compressed by a tumour which cannot always be detected by physical examination (Barton 1973). Furthermore, cases like the present four will often be cured by decompression

Exploration was done by an antero-lateral incision with free dissection of the nerve as shown in Figure 2 (after Mayer & Mayfields 1947)

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Acta orthop scand 47 308–310 1976

SURGICAL TREATMENT OF ACROMIOCLAVICULAR DISLOCATION

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The results of surgical treatment of 17 patients with complete acromioclavicular dislocation are presented The operative procedure described is technically easy gives good results has few complications and is not associated with the complications which often follow operations using metallic fixation devices A second operation to remove fixation devices is avoided

Key words injury, dislocation acromioclavicular joint operative treatment

Accepted 7 i 76

It is generally thought that complete dislocation of the acromioclavicular joint with disruption of the coracoclavicular and of the acromioclavicular ligaments should be surgically treated, whereas contusion and subluxation show good results with non operative treatment (Sage & Salvatore 1963) The surgery usually consists of anatomical reduction and reconstruction of the acromioclavicular ligaments with or without internal fixation of the joint

In this paper a simple operative technique without the use of metallic fixation devices, either in the joint or for the stabilization of the coracoclavicular ligaments, is described and the results discussed

PATIENTS AND METHODS

Between 1965 and 1973 17 patients with complete dislocation of the acromioclavicular joint were operated on in Telemark Central Hospital's surgical and orthopaedic departments

The same operative procedure a modification of Watkin's method (1925) was used in all patients A slightly curved incision is made under the lateral portion of the clavicle the acromioclavicular joint is exposed and freed from interposed capsule and ligaments Approximating sutures are inserted but not tied until after the reduction of the clavicle The pectoralis major muscle is divided at its clavicular origin and the disrupted coracoclavicular ligaments are exposed The ends of the ligaments are identified and approximating sutures are inserted but not tied until later The most important step in the operation is to maintain an anatomic reduction of the clavicle For this purpose we have used a twice doubled strong nylon suture 0 40 mm The suture is attached around the coracoid process and the clavicle and then the clavicle is reduced With the clavicle in exact anatomical position the four nylon sutures are tightened and tied The sutures in the coracoclavicular ligaments are tied and then the wound is closed The arm is placed in a sling and the patient begins careful exercises on the first postoperative day

All the patients were males with an average

age of 36 years (range 17 57 years) In eleven patients the left and in six the right shoulder was injured. Six patients were injured in traffic accidents five in sports accidents three had fallen off a ladder two had fallen down stairs and one patient fell down a slope None of them had other bone or soft tissue injuries Sixteen patients were operated on within 1 week of injury and one after 17 days

RESULTS

All the 17 patients were followed up, the mean observation period being 52 months Thirteen were examined clinically and four answered a questionnaire One patient developed a postoperative wound infection which healed with the use of antibiotics in the course of 17 days The nylon thread was not removed

Thirteen patients were completely free of symptoms, the shoulder being as good as before injury Two patients felt that their arm was somewhat weaker than before but otherwise had no complaints Two other patients were not satisfied with the result because of pain and weakness Neither of these two patients, however, came to the follow up examination The thirteen patients who were clinically examined had no symptoms of pain weakness or loss of motion The two patients who complained of moderate weakness had no signs of muscle atrophy or loss of muscle power Fifteen patients stated that they were able to do the same amount of physical activity as before the injury There was one case of suture suppuration 4 years after operation which ceased after the nylon sutures were removed Another patient had an ugly scar because of keloid formation

DISCUSSION

Complete dislocation of the acromioclavicular joint is relatively uncommon However the increasing number of traffic and industrial accidents, as well as the increasing participation in sport, has led to a corresponding increase in the incidence of the injury (Seitz et al 1972) Clinical diagnosis is not difficult provided the possibility is kept in mind X ray examination of both shoulders with "hanging" arm is usually helpful, and may also show other skeletal injuries in the same area In the event of multiple injuries, one must be alert to the possibility of an acromioclavicular joint dislocation as it can easily be overlooked

We consider that complete dislocation with injury to the acromioclavicular ligaments and total separation of the coracoclavicular ligaments should be operated on as soon as possible after the injury

The technique presented with no implantation of metal, is simple and gives good results It is essential that the clavicle is anatomically reduced, the torn ligaments are reconstructed, and the joint stabilized until the ligaments have healed

The use of temporary metallic internal fixation has been shown to have several disadvantages because of complications from the fixation material, e g, migration of the fixation pins, bone erosion, re dislocation due to failure of the metallic fixation devices, development of acromioclavicular arthralgia, a greater risk of infection, and the necessity of a second operation to remove the fixation material (Weaver & Dunn 1972)

CONCLUSION

A technically simple procedure is described which has few complications, gives good results and is not encumbered with the complications often associated with temporary metallic fixation, including the necessity of a second operation for removal of the fixation devices

The author recommends surgical treatment of complete dislocation of the acromioclavicular joint The operation

should be performed as soon as possible after the accident

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Acta orthop scand 47, 311–316, 1976

RING TOTAL HIP REPLACEMENT IN OSTEOARTHROSIS

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A follow-up is given of the results of 40 arthroplasties with the non cemented, vitallium to vitallium bearing Ring total hip prosthesis in 37 patients with osteoarthrosis Operative indication was an intolerably painful and stiff joint The surgery was performed by two specialists in orthopaedics Point scores according to a modification of Merle d Aubigné s classification showed excellent or at least good results in 52 5 per cent, and fair results in 27 5 per cent of the operations One prosthesis was removed because of deep infection The mortality rate was zero In 20 per cent the total score was between 0 and 7, signifying little or no improvement Loosening was the main problem even although it was in many cases well tolerated by the patients

Key words Ring total arthroplasty, hip joint, osteoarthrosis

Accepted 3.xii 75

This article deals with the analysis of 40 total hip replacements performed by the authors during the period May 1968 to May 1974 An attempt has been made to judge the result very critically, in addition to making use of the numerical evaluation of the hip joint according to Merle d Aubigné, as modified by pain thresholds Efforts have also been made to point out the categories of failure and the reasons for dissatisfaction regarding the treatment

MATERIAL AND METHODS

Endoprosthetic reconstruction of the hip joint with the non cemented Ring vitallium 150° shaft neck angle prosthesis (Figure 1) was performed during the period May 1968 to May 1974 on 40 hip joints of 21 male and 16 female patients at the Department of Surgery, Oulu University Hospital, Finland

The majority of the patients were elderly (mean age 61 years, age range 44–74 years) Operative indication was degenerative osteoarthrotic changes in the hip joint (Figure 2), in one instance secondary to rheumatoid arthritis (Table 1)

The follow up examination was performed in all cases by the research group personally The mean length of the observation period was 3 years, range 1–6 years The total mortality rate was zero

In calculating the results a modified system of Merle d Aubigné was used for summing up the point score for mobility, pain, and walking ability However, the total score is indicated separately (Tables 2, 3)

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after 5 days on average

Also presented at the VIII European Rheumatology Congress in Helsinki June 1–7, 1975 as a part of the workshop on "Arthroplasty of the hip



Figure 1 The non-cemented, metal-to-metal bearing, Ring total hip joint The fenestrated self locking femoral component has a neck valgus angle of 150° and a standard head of 40 mm in diameter The screw by which the cup is fixed is tapered This anteroposterior roentgenogram shows the situation immediately after operation

RESULTS

The pre- and postoperative scores for mobility, pain, and walking ability are summed up in Table 4 Every patient selected for operation had very severe osteoarthrosis as shown by the preoperative score The end-results in every fifth patient had to be classified as not improved whereas 52 5 per cent of all patients belonged to the group with good or excellent results (Table 5) The reasons for failure fell into two categories: early and late complications These are reported in detail below

Early complications (Table 6)

During the hospital stay deep vein thrombosis was diagnosed in two patients; however, it was possible to treat this by conventional medical means without late sequelae at the time of follow-up

Deep infection led to removal of the prosthesis and a spontaneous Girdlestone joint in one patient A chronic low grade fistulous infection in another was treated with antibiotics and did not require removal of the prosthesis Both were classified as failures

Transient peroneal paralysis in two patients did not affect the favourable outcome No dislocations occurred The mortality was zero

Late complications (Table 6)

Loosening of the stem occurred frequently and seemed to be the main reason for failure A radiolucent zone surrounding the prosthesis was seen in

Table 1 Operative indications in recent follow-up series

	Ring (Great Britain) (1974)	Evarts et al (USA) (1972)	Leinbach & Barlow (USA) (1973)	Paaby (Denmark) (1974)	Lindholm & Puranen (Finland) (1975)
No of joints	1000	25	40	400	40
Years	1964–74	before 1971	1968–73	1968–74	1968–74
	Per cent	Per cent	Per cent	Per cent	Per cent
Arthrosis	89 0	50 0	57 5 (approx)	100	97 5
Rheumatoid arthritis	3 7	15 6	7 5 (approx)	0	2 5
Other	7 3	34 4	35 0 (approx)	0	0 0



Figure 2 Intolerably painful bilateral primary osteoarthrosis with almost total loss of hip movements in a female aged 67 illustrates the most readily accepted operative indication in this series

Table 2 Numerical evaluation of the hip joint according to d Aubigné

Score	Pain	Mobility	Walking ability
0	Very severe continuous pain	Ankylosis with bad position of the hip	Unable to walk
1	Very severe pain preventing sleep	Clinical ankylosis with little or no deformity	Only with crutches
2	Severe pain on walking Inhibited in all work	Flexion 0–40° Abduction 0° or slight deformity	Only with 2 sticks
3	Tolerable pain interfering with work	Flexion 0–60°	Less than 1 hour with stick Very difficult without stick
4	Only pain after walking Subsides on resting	Flexion 0–80° Able to lace shoes	1 stick for long distances Limited without stick
5	Negligible and intermittent pain not interfering with work	Flexion 0–90° Abduction $< 25°$	A slight limp with a stick
6	No pain	Flexion $> 90°$ Abduction $> 25°$	Normal

the roentgenograms in 16 cases, of which 12 only had changes around the acetabular component Four patients showed migration of the femoral portion However it is evident that the patients with this complication can be divided into two groups the tolerable loosenings and the loosenings requiring revision

Reoperation was performed in five cases four prostheses were changed to Christiansen s total prosthesis and one to Moore s endoprosthesis At replacement

Table 3 System of classification of end result on the basis of total score modified by pain thresholds

End result	Score	Criterion
Poor	0–7	pain 0–2
Fair	8–12	pain >3
Good	13–16	pain >4
Excellent	17–18	

it was found that both components had loosened in two cases but only the acetabular component in three cases

In one patient the reason for pain was unclear after the examinations and the lack of improvement had to be classified as psychogenic

DISCUSSION

Ring's own experience from his earlier and later operations show clearly a considerable improvement in the results, a fact which seems to be closely related to the development of the prosthesis since then (Ring 1974) Ring's first model has been changed and the new modifications are now in current use The principle of metal-to-bone fixation without cement has remained unchanged Only architectural adjustments have been made Tapering the screw of the acetabular component (Figure 1) has possibly improved its long-term grip in comparison with the older parallel moulded device (Figure 3)



Figure 3 One of the earliest operated hips followed up for 6 years a male aged 68 Axial roentgenogram shows a halo effect around the non tapered screw used in some of the earlier replacements This is a positive indication of loosening Symptoms however, were tolerable The stem of the femoral component is rigidly fixed by a grip of heavily calcified spongious bone, especially concentrated in the region of the neck and the holes of the stem With the passage of time bone is formed, which counteracts loosening and/or migration

Loosening has no doubt been a problem, in our series and in others (Evarts et al 1972, Leinbach & Barlow 1973), but the need for revision has decreased (from 3 7 per cent to 1 6 per cent) as indicated

Table 4 Pre and postoperative scores of 40 patients with the Ring prosthesis

Score	Mobility score of the hip No of cases Preop	Mobility score of the hip No of cases Postop	Pain score No of cases Preop	Pain score No of cases Postop	Gait score No of cases Preop	Gait score No of cases Postop
0	1	–	–	1	–	–
1	4	–	6	1	4	3
2	28	2	33	6	7	5
3	7	9	1	5	29	10
4	–	13	–	7	–	7
5	–	10	–	11	–	15
6	–	6		9	–	–

Table 5 Results

	Ring (1974) Earlier (169)	Ring (1974) Later (535)	Evarts et al (1972) (25)	Leinbach & Barlow (1973) (40)	Paaby (1974) (400)	Lindholm & Puranen (1975) (40)
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Excellent	45	69	12	Satisf 90	61	17.5
Good	29	21	24	Not satisf 10	34	35.0
Fair	10	6	24		4	27.5
Poor	16	4	40		1	20.0

Table 6 Complications

	Ring (1974) (1000)	Evarts et al (1972) (25)	Leinbach & Barlow (1973) (40)	Paaby (1974) (400)	Lindholm & Puranen (1975) (40)
	Per cent	Per cent	Per cent	Per cent	Per cent
Mortality	1.1	0	0	0.5	0
Morbidity					
cerebral thrombosis	0.2				
g.i. haemorrhage	0.5				
deep vein thrombosis	7.0	50	7.5		5.0
Dislocation	0.3	(1)	0.0		0.0
Deep infection	0.7	(1)	0.0	0.7	5.0
Metal failure	0.5				0.0
Loosening	3.7–1.6	40	10.0	1.5	12.5* + 27.5†
Replacement anchylosis	0.7				
Peroneal paralysis					5.0
Stress fracture in acetabular rim					2.5

* Revisions
† Tolerated

by Ring's earlier and later performances. It is of interest to note that loosening often remains a subclinical problem (Leinbach & Barlow 1973) and that the joint in such cases is in fact quite satisfactory and more functional than before replacement (Figure 3), even reversibility of so called loosening in its early stages has been observed. The risk of deep infection is a serious problem in all types of endoprosthetic surgery, because if it cannot be satisfactorily treated by conventional revisions and antibiotics the prosthesis has sooner or later to be removed. This may be a difficult and traumatizing operation if cement has been used. With Ring's prosthesis it is an easy procedure and less traumatizing. Osteophytic overgrowth, known from the earlier days of femoral head replacements in osteoarthrosis, has not been encountered with Ring's prosthesis. Mortality is very low in all series, a fact related to the selectivity of this operation, which has to be carefully planned and performed without undue haste. Our experience with the Ring total hip replacement gives no cause for disagree

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DISCUSSION

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	Preop	Postop	Preop	Postop	Preop	Postop
0	1	–	–	1	–	–
1	4	–	6	1	4	3
2	28	2	33	6	7	5
3	7	9	1	5	29	10
4	–	13	–	7	–	7
5	–	10	–	11	–	15
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	Per cent	Per cent	Per cent	Per cent	Per cent
Mortality	1 1	0	0	0 5	0
Morbidity					
cerebral thrombosis	0 2				
g i haemorrhage	0 5				
deep vein thrombosis	7 0	50	7 5		5 0
Dislocation	0.3	(1)	0 0		0 0
Deep infection	0 7	(1)	0 0	0 7	5 0
Metal failure	0 5				0 0
Loosening	3 7–1 6	40	10 0	1 5	12 5* + 27 5†
Replacement anchylosis	0 7				
Peroneal paralysis					5 0
Stress fracture in acetabular rim					2 5

* Revisions
† Tolerated

by Ring s earlier and later performances It is of interest to note that loosening often remains a subclinical problem (Leinbach & Barlow 1973) and that the joint in such cases is in fact quite satisfactory and more functional than before replacement (Figure 3) even reversibility of so-called loosening in its early stages has been observed The risk of deep infection is a serious problem in all types of endoprosthetic surgery, because if it cannot be satisfactorily treated by conventional revisions and antibiotics the prosthesis has sooner or later to be removed This may be a difficult and traumatizing operation if cement has been used With Ring's prosthesis it is an easy procedure and less traumatizing Osteophytic overgrowth, known from the earlier days of femoral head replacements in osteoarthrosis, has not been encountered with Ring s prosthesis Mortality is very low in all series, a fact related to the selectivity of this operation, which has to be carefully planned and performed without undue haste Our experience with the Ring total hip replacement gives no cause for disagree

ment with Ring's conclusions and recommendations regarding indications and techniques (Ring 1974, Ring 1975)

We recognize that our results are not without fault and particularly loosening of the acetabular component has been a problem According to Evarts et al (1972) there has been a progressive decline in point scores with the passing of time and they have concluded that the usefulness of the Ring prosthesis at present seems to be limited We are, however, not so pessimistic and favouring the non-cemented type of fixation and the metal-upon-metal bearing one of us (R L) still uses the Ring total hip replacement

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Acta orthop scand 47, 317–319, 1976

FALSE ANEURYSM OF THE EXTERNAL ILIAC ARTERY FOLLOWING HIP ENDOPROSTHESIS

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A false aneurysm developed from the external iliac artery within the pelvic cavity following total hip surgery when methylmethacrylate cement had been used to fix the cup The aneurysm was probably caused by a cement spicule which had entered the pelvis and had come into contact with the external iliac artery

Key words arthroplasty, hip, cement spicule, arterial aneurysm

Accepted 6 i 76

The two most common complications of total hip replacement are loosening of the prosthesis from its attachment, and infection There are also a large variety of complications associated with the different methods employed and which occur with different frequencies Recently, false aneurysm arising as a result of the prosthesis coming into contact with a major vessel has been reported by Hierton et al (1973), Kroese & Möllerud (1974) and Dorr et al (1974)

In view of the rare occurrence of this complication it may be of interest to report a recent case that has come to the author's notice

CASE REPORT

A McKee total hip replacement was performed in a woman of 57 years suffering from rheumatoid arthritis The diagnosis had been made 20 years earlier She was able to walk short distances with a stick. She suffered from severe night pain A roentgenogram of the hip joint showed destruction and marked acetabular protrusion (Figure 1) McKee total hip replacement was performed on October 12, 1973 Posterior curved exposure (southern exposure) was used Post operative radiographs showed the prosthesis to be in the varus position, fairly deep in the pelvis

The immediate postoperative course was normal, and no prophylactic or postoperative anti biotic therapy was given Her right hip could be flexed 90°, and there was no hip extension contracture, abduction was 15°, adduction 20°, external rotation 15° and internal rotation 10° About 8 months later a fistula appeared, with no previous pain or pyrexia The patient was able to walk with the aid of a stick and without pain Radiographs showed no change in the position of the prosthesis and no evidence of bone resorption or osteitis (Figure 2) It was planned to explore the fistula and, if necessary, to per form curettage and suturing, but on admission to hospital pain developed in the groin Palpa tion revealed the presence of a deep, slightly pulsating, resistant swelling Auscultation disclosed a slight murmur There was a blood stained discharge on the fistula changing later to pure blood Arteriography disclosed the pres ence of a false aneurysm of the external iliac artery (Figure 3)

On exploration it was found that some of the methylmethacrylate cement used to attach the prosthetic cup to the pelvis bone had entered the pelvis through a drill hole, and that a projecting spicule of the cement was in contact

ment with Ring's conclusions and recommendations regarding indications and techniques (Ring 1974, Ring 1975)

We recognize that our results are not without fault and particularly loosening of the acetabular component has been a problem According to Evarts et al (1972) there has been a progressive decline in point scores with the passing of time and they have concluded that the usefulness of the Ring prosthesis at present seems to be limited We are, however, not so pessimistic and favouring the non-cemented type of fixation and the metal-upon-metal bearing one of us (R L) still uses the Ring total hip replacement

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On exploration it was found that some of the methylmethacrylate cement used to attach the prosthetic cup to the pelvis bone had entered the pelvis through a drill hole and that a projecting spicule of the cement was in contact

with the external iliac artery. Close to this spicule a false aneurysm had formed in the vessel; this formation was found to communicate with the fistula. The cement spicule was removed, and the aneurysm isolated and closed with a patch. The postoperative course was satisfactory.

DISCUSSION

Many reports of complications in total hip replacement have been published. Much attention has been devoted to postoperative infection, loosening of the endoprosthesis, and pulmonary and cardiovascular responses elicited by the monomeric methylmethacrylate in the fluid component of the cement.

Arterial trauma and false aneurysm of the large vessels seem to be rare complications of arthroplastic surgery. In this patient the false aneurysm developed after laceration of the external iliac artery by a cement spicule which had



Figure 1. Preoperative roentgenogram. Marked acetabular protrusion in the right hip.



Figure 2 Eight months after total h p replacement Barium sulphate does not mix with the methylmethacrylate



Figure 3 Ang ogram The false aneurysm in the external iliac artery is seen as a rad opaque mass

entered the pelvis Gradual erosion of the arterial wall occurred The false aneurysm developed 8 months after operation

In view of the rarity of false aneurysm following hip endoprosthesis it is doubtful whether specific preventive measures are indicated when using ordinary surgical techniques To fix the prosthesis in the pelvis it is necessary to use one or more drill holes to gain stability The direction of these holes is important as contact with any of the larger vessels in the pelvis must be avoided

Special care must be taken when drilling the pelvis of patients with acetabular protrusion In such patients the large pelvic vessels lie closer to the acetabulum and laceration of arteries or veins readily occurs

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Figure 1. Preoperative roentgenogram. Marked acetabular protrusion in the right hip.

Table 1 Patient material distributed according to method of operation

	No of cases
Operations using endoprosthesis + acrylic cement (total hip replacement 65 cases)	71
Operations using *AO* plate *for fixation*	22
Operations using Nystrom or van Bahr nails	10
Operations of other types (e g elective operations for extraction of material for osteosynthesis)	4
Total	107

ciples was emphasized The operating theatres used belonged to a 15 room central operation department Altogether 107 patients were included in this study (Table 1) In 18 cases parenteral treatment with benzylpenicillin was begun at the time of the operation as prophylaxis against infection a routine measure for operations lasting more than 90 min The investigation was extended to the third postoperative week The samples for bacterial culture were all collected in the orthopaedic wards The following routines were used

a In all cases of hip surgery a blood plate was pressed against the skin at the trochanteric region before disinfection of the skin

b A sample from the drain fluid was taken when the drain container was emptied after operation For this a sterile cotton stick was dipped into the drain fluid and put into an anaerobic transport tube (anaerobic culture tube Labora) which was one third *filled with* Stuarts medium and two thirds filled with O_2 free CO_2 gas

c When no more drain fluid could be collected *the drains were removed Before* removal of the drain a sample was taken at the site of *perforation of the skin using* a cotton stick soaked in saline which was then transferred into *an anaerobic transport tube* (see above) Two cm of the inner part of the drain tube was cut off and put into an anaerobic transport tube

Using the method described by Moore (1966) *the transport tubes for anaerobes* were opened in O_2 free CO_2 gas The skin blood plates (a) were incubated aerobically at 37° C *for 24 h* The two cotton sticks (b + c) were used to streak blood and *haematin agar* plates Finally these sticks were used to inoculate an extract bouillon and an anaerobic trypticase soy broth (BBL) All media were incubated at 37° for 48 h The culture media were examined after 24 and 48 h before they were discarded

The identification of the bacteria was performed according to Cowan & Steel (1970) Bacteria of the same species were accepted as identical if they also showed the same antibiogram in analysis with a panel of nine antibiotics

A positive culture from the drain was regarded as indicating the presence of the actual organism in the surgical wound The same is valid for a positive culture from the tip of the drain except for a few cases when the same organism was *also found on the skin at the site of perforation* by the drain

FINDINGS

The bacteria isolated from the skin are seen in Table 2 In some patients several species were isolated

Patients without prophylactic antibiotic treatment (89 patients See Table 3) Only one patient developed a deep wound infection requiring surgical treatment This was a 76-year old man suffering from coxarthrosis Arthroplasty with a total hip prosthesis and acrylic cement was performed After the operation fever and symptoms from the wound indicated an infection Clostridium welchii was isolated from the two drains inserted at the

Table 2 Microorganisms cultured from the skin before operation

Microorganism	No of cases	Per cent of total
Staph albus	94	88
Staph aureus	23	22
β-streptococcus pyogenes (Group A)	1	1
α haemolytic streptococcus	6	6
Streptococcus faecalis	6	6
Diphtheroid rods (aerobic)	2	2
Bacillus species	13	12
E coli	3	3
Pseudomonas species	5	5
Candida albicans	1	1
Yeasts not specified	1	1
Total number of patients	107	

Acta orthop. scand. 47, 320–323, 1976

BACTERIA IN HIP SURGERY

A Study of Routine Aerobic and Anaerobic Cultivation from Skin and Closed Suction Wound Drains

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One hundred and seven patients with closed suction wound drains after hip surgery were investigated with regard to bacteria in the drain. In one third of the cases bacterial contamination of the wound was found. In more than half the total number of cases the bacteria in the wound were not identical with those found on the skin either pre- or post-operatively. Anaerobe bacteria occurred only in one case. Penicillin administration considerably reduced the frequency of positive cultures. These findings support the prophylactic use of antibiotics in the prevention of late infections in endoprosthesis operations even when the early infection rate is satisfactorily low.

Key words: wound infection, hip, drainage, antibiotic

Accepted 15.i.76

Wound infections are still a major problem in surgery and the literature on this topic is extensive; this is partly due to diverging and inconclusive definitions of "wound infection". The presence of pathogenic microorganisms in the operative wound may, however, be regarded as the central problem. The virulence, the number of microorganisms and the local conditions influencing their growth are some important factors which determine whether clinical infection will occur or not. The use of large implants may also result in complications from bacteria earlier regarded as apathogenic. Thus, the bacteria "normally" found in operation wounds are becoming increasingly interesting. The aim of this investigation was to study the frequency of different bacteria in the wound postoperatively, their correlation with the cutaneous flora and the symptoms from the wound. Since the problems of infection are at present of great importance, particularly in hip surgery, a material of "clean" hip operations was used for the study.

MATERIAL AND METHODS

The study was carried out at the Departments of Orthopaedic Surgery and Clinical Bacteriology at the University Hospital of Umeå. Only cases of clean hip surgery operated on in the years 1973 and 1974 in which closed suction drains were applied are included. Operations performed during the summer months each year when the majority of the regular staff members were on vacation were excluded. No special routines such as a "clean air chamber" or local installation of antibiotics were used but operating room discipline according to standardized surgical prin-

ifested infections The results of these observations indicate that a variety of organisms generally contaminates the operation wound, and that some strains were detected by a positive culture and in a few cases some strains caused clinical infection

In this study the infection dose seems not to have been reached in most cases As indicated by Kamme et al (1974), low virulent bacteria otherwise regarded as apathogenic (e g staph albus), may be involved in the so called late infections occurring after endoprosthesis operations Bacteria of this group were in this investigation frequently isolated from the inside of the wound In the investigation of Kamme et al (1974) anaerobe bacteria were not found to be uncommon in late infections Against this background it is interesting to note that anaerobes were rarely isolated from the wound in this investigation at the early phase after the operation The discrepancy may be due to the low number and to the slow growth of anaerobes in the operation cavity at this early stage after the operation The anaerobe bacteria found by Kamme et al (1974) could also have reached the area later i e by haematogenous infection

Recent findings by Ericson et al (1973) indicate that prophylactic treatment with antibiotics significantly reduces the number of early as well as late infections However the opposite results have been reported by Tachdjian & Compere (1957) In this investigation a smaller number of positive cultures from the wounds in the group treated with penicillin was obtained as compared to the group without treatment

Since the incidence of clinical infection is strongly influenced by the size of the infection dose our results suggest that even under good conditions (i e an actual frequency of early deep infection of about 1 per cent), bacterial contamination in hip surgery occurs in about 30 per cent of all cases This may mean that, despite the low incidence of early deep infections, there is a high risk of late infections at operations where endoprostheses are used This supports the use of prophylactic treatment with antibiotics at every operation where a potential risk of late infection exists, even if the early infection rate is usually low

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Table 3 Patients not treated with antibiotics (89 cases) tested for bacterial growth in the drain fluid and the tip of the drain

Microorganism	No of cases		Per cent of positive culture
Staph albus	15	32	47
Staph aureus	6		19
α-haemolytic streptococcus	4		13
Streptococcus faecalis	3		9
Diphtheroid rods (aerobic)	2		6
Clostridium perfringens	1		3
Aeromonas sp	1		3
No growth	57		

operation and the same organism was later cultured directly from the wound

In 32 patients (36 per cent) bacteria grew in cultures from the wounds (Table 3). Apart from the case referred to above only aerobic bacteria were detected in the remaining cases Of these patients with positive bacterial cultures from their wounds, 10 (31 per cent) had the same organism present in the preoperative skin culture, and six (18 per cent) had the same organism at the site of perforation of the skin by the drain

In 16 patients (18 per cent) symptoms from the operation wound were noted, e g slight secretion, haematoma or redness Since these symptoms were neither severe nor long-lasting none of these patients was regarded or treated as having a wound infection In this group bacteria were isolated from the drain in 11 cases (69 per cent) (Table 4) From some patients several bacterial species were isolated

Table 4 Patients not treated with antibiotics postoperatively (16 cases) but with symptoms from the wound Species isolated from the drain fluid and from the tip of the drain

Microorganism	No of cases	Per cent of positive culture
Staph albus	6	38
Staph aureus	5	31
Streptococcus faecalis	1	
Diphtheroid rods	1	
Bacillus sp	1	
Clostr perfringens	1	
Aeromonas	1	
No growth	5	

Among the 73 patients without any clinical symptom of infection 21 (29 per cent) had bacteria in the drain

Patients treated with penicillin prophylactically (18 patients) In three cases bacteria were cultured from the drains (Staph albus, two cases, Bac subtilis, one case) Two other patients had symptoms from the wound but were not regarded as having wound infections

DISCUSSION

Thirty-one per cent of the patients with bacteria cultured from the wounds had the same organism in the preoperative skin culture About 18 per cent had the same bacteria at the drainhole as in the wound Thus more than 50 per cent of the bacteria in the wound seem to have come from sources other than the patient or from localisations on the patient other than the operation area

A positive culture was about twice as common in the group of patients with symptoms from the wound as in the whole material This indicates that in this group patients with transient wound infections or wounds containing haematoma or/and necrosis leading to diminished resistance to bacteria are also included Deep wound infection occurred in only one case in the present series Bacteria were, however, found in the wound in about one-third of the total number of cases Earlier reports by Howe (1964), Howard et al (1964), Fitzgerald et al (1973) also suggest that bacterial contamination of the operation wound is much more common than clinically man-

dary to osteochondritis O A after cup arthroplasty (cup and neck removed elsewhere) high C D H pseudarthrosis following fracture of the femoral neck operated neck fracture–aseptic necrosis operated neck fracture with pseudarthrosis aseptic necrosis operated fracture of the neck pseudarthrosis infection pseudarthrosis of the neck and fracture–Austin Moore removal rheumatoid arthritis with dysplasia of left hip aseptic necrosis of head because of sickle cell anemia septic arthritis of the hip

All patients presented with severe limitation of movement severe or very severe pain and limp Some were crippled to such an extent that they were unable to get out of bed unaided

METHODS

Skeletal or skin traction was applied for 12 weeks and the patients *received a course of* physiotherapy Weightbearing was gradually started 3 months after the operation

The long post-operative period was aimed at

1 Avoiding marked shortening and lateral rotation of the limb
2 Achieving a satisfactory range of active movement
3 Reducing the instability of the hip to some extent

Additional operations on the operated hips were performed in five cases (two subtrochanteric osteotomies two iliopsoas transfers and one tenotomy of adductor) Five operations were performed on the contralateral hip (*one arthrodesis* of the hip one Pawels osteotomy one intramedullary nailing of the femur one arthrodesis of the knee and one triple arthrodesis) There were six post operative complications viz one thrombophlebitis one *pulmonary embolism* and four infections all of which were treated conservatively except for two of *the infections* which were treated by surgery

RESULTS

The following parameters were taken into consideration for the assessment of the results of the operation pain range of movement gait patient s opinion These were studied separately and in relation to the type of disease, the patient s age and the time elapsed since the operation The final assessment of our results was based on the above mentioned factors

Pain

This is assessed in various ways by the different patients a fact which renders its grading difficult and inaccurate Our patients were, nevertheless, divided into five groups

1 *No pain* The operated hip was not painful even after exercise

2 *Slight pain* Temporary pain, especially after exercise, which did not interfere with the patients' activities and was not taken into consideration by them

3 *Medium pain* Pain even after light exercise, which interfered with normal activities, but disappeared with rest or analgesics

4 *Severe pain* Continuous pain, worse after exercise greatly influencing the patients' activities, and *only improving* with rest or analgesics

5 *Very severe pain* Continuous pain, *rendering* work impossible, keeping the *patient* bedridden for long periods and finally causing complete *disablement*

All patients presented pre-operatively severe or very severe pain Reference is made to 43 patients not to 48 hips as it was found that the bilateral operations gave similar results in both hips

Assessment according to the type of disease The results of Girdlestone's operation regarding pain are as follows No pain, 11 patients (26 per cent) slight pain, 20 patients (46 per cent), medium pain, 8 patients (19 per cent), severe pain, 3 patients (7 per cent), and very severe pain, 1 patient (2 per cent), i e 72 per cent of the patients were relieved *from* pain or had only slight complaints The nature of the disease does *not* seem to be correlated with the results *of the* operation It is interesting to note *that* very severe and paroxysmal pain in the case of sickle cell anemia was not modified by the operation

Assessment according to the age of the patients The patients were divided into three groups The first group included

Acta orthop scand 47, 324–328, 1976

GIRDLESTONE'S OPERATION: A FOLLOW-UP STUDY

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A study was made of 43 patients (48 hips) operated for diseases of the hip using Girdlestone's method The follow-up time ranged from 2.5 to 13 years For assessment of the post operative results the following parameters were taken into consideration pain range of movement gait and the patient's opinion These were studied separately and in relation to the type of disease, the patient's age, and the time which had elapsed since the operation Pain decreased in a considerable number of the patients and range of movement and gait improved The patients were generally in favor of the operation, and felt it had had a beneficial effect on their condition

Key words Girdlestone's operation, assessment of results, hip disease

Accepted 3 xi 75

The removal of the head and neck of the femur is one of the time-honored operations used for the management of diseases of the hip (Schmalz 1817 and White 1824, quoted by Francillon 1934, Fock 1861, Blenke 1899) It was brought to notice by Girdlestone (1945), whose name it now bears, and has been used by him in cases of tuberculosis and/or a variety of painful conditions of the hip joint which were resistant to conservative treatment

As a method of operative treatment of osteoarthritis of the hip, Girdlestone's operation has lost much of its appeal in the last few years, with the coming of total arthroplasties of the hip However, there appears to be a renewed tendency to use this method, since the period of completely satisfactory function of total prostheses has passed, and there are instances where this operation has been unsuccessful

MATERIAL

Between the years 1958 and 1969, 54 patients underwent Girdlestone's operation for a variety of diseases of the hip Forty three of these patients were re-examined Out of the remaining 11, two had died one had a total arthroplasty at another hospital and eight could not be traced Out of 43 patients followed up, 40 were female (93 per cent) and three were male (7 per cent) The age of the patients ranged from 17 to 79 with an average of 50 Thirty two patients presented with bilateral lesions five with right hip and six with left hip lesions

In the majority of patients with bilateral involvement (osteoarthritis) only the hip with the more severe symptoms was operated upon However five patients underwent bilateral surgery four of them because of osteoarthritis and one because of rheumatoid arthritis Thus the operation was performed on 48 hips, 27 right and 21 left hips In two cases of high congenital dislocation of the hip the procedure was followed by subtrochanteric osteotomy of the Milch Batchelor type

The patients suffered from the following conditions Osteoarthritis (O A) secondary to congenital dislocation of the hip (C D H), O A secon

groups as already mentioned but in this case the number of operated hips is recorded)

The average index of active movement in the first group was pre operatively 28 7 and post operatively 41 4, in the second group it was 31 9 and 43 4 and in the third group 27 5 and 40 3, respectively Thus it is obvious that the period of the time elapsed since the operation does not influence the range of movement of the hip The improvement in range of movement, which was achieved with the operation, remained almost unchanged with the passing of time

Gait

The following factors make the influence of the operation on gait difficult to assess

1 Lesions of the contralateral hip (bilateral O A) *may influence the gait* with the *passage of time*
2 An operation may have to be performed on the contralateral hip
3 Operations on a lower limb *may* influence the gait Such cases were included in our series

At follow-up in all cases limping was noted to a *varying degree*

The patients were divided into three groups according to the following parameters

Stick, crutches wheelchair, distance, activity

1st group Patients with a *slight limp* and good stability of the *hip*, walking without help and coping well *with daily* activities *2nd group Patients with* an obvious limp and a degree of instability, walking with a stick looking after themselves, but unable to work *3rd group* Patients with a *marked* limp and great instability, walking with sticks or crutches or in a wheelchair, and having *difficulties* in looking after themselves

Assessment according to the type of disease Out of a total of 43 patients, 15 belonged to the first group (35 per cent), 14 to the second (33 per cent) and 14 to the third group (33 per cent)

A careful study of the results as regards walking in relation to the type of disease showed that the gait was unaffected by the particular disease for which the operation was performed

Assessment according to age When the patients were divided according to the classification given above, there were 15 in the first group (35 per cent), 14 in the second (33 per cent), and 14 in the third group (33 per cent)

A careful assessment of the results of the operation in relation to walking ability in the various age groups showed that there was a greater percentage of young patients in the 1st group (age 15–35, 57 per cent), while middle-aged patients *predominated* in the 2nd group (age 35–55, 39 per cent) and there were more older patients in the 3rd group (age 55 and over 50 per cent) Th [illegible]
ability

Assessn [illegible] *since the operation* Division of the patients according to the same classification of walking ability showed that 15 patients belonged to the 1st group (35 per cent), 14 to the second (33 per cent) and 14 to *the third group (33* per cent)

A careful study of the results of the *operation* as *regards gait* (with reference *to* the period of time elapsed since the operation) showed that the number of *patients* in the 1st group decreased with the passage of time, whereas the number *of patients* in the second group increased, and the number in the third group remained *stable* Thus, the longer the period *of* time since the operation the poorer the walking ability (The patients pass from the first group to the second)

Personal opinion of the patients

The opinion of the patient should be *seriously* considered in the general as-

patients operated upon between the ages of 15 and 35 (7 patients), the second group included patients aged 36 to 55 (28 patients) and the third group included patients over 56 (8 patients)

Three of the seven patients (42 8 per cent) in the first group were free of pain while 13 patients (44 8 per cent) in the second group (middle age) and 5 (62 5 per cent) in the third group (old age) had only slight pain

Assessment according to time elapsed since the operation The patients were divided into three groups 1st group reviewed 2 5 to 6 years after operation (14 patients), 2nd group reviewed 7 to 9 years after operation (12 patients), 3rd group reviewed 10 to 13 years after operation (17 patients)

Severe pain was noted in the recently operated patients In the 1st group there were three patients with severe pain (21 per cent), in the 2nd and 3rd groups there were no patients with severe pain The percentage of patients with medium or slight pain did not seem to be related to the time elapsed since the operation There were slightly more patients with no pain in the 3rd group (5 patients, 29 4 per cent) Thus the pain seemed to diminish with the passing of time

Motion

To assess the results of the operation on hip movements the following parameters were taken into consideration

1 Active movement of the joint pre- and post-operatively
2 The range of passive movement which was achieved

Assessment of movement was made according to the criteria of Shepherd (1954) and Gade (1947)

Assessment according to the type of disease In 48 operated hips the smallest active motion index, pre-operatively was nil and the largest 61 (average 29 8) The operation was obviously performed on patients with severe or very severe pain who presented also a marked limitation of hip movement

Post-operatively the smallest index was 12 and the largest 69 (average 41 5) Thus the operation caused a marked improvement in active movement of the hip (79 per cent) In 10 cases (20 per cent) the range of movement was reduced and this applied to seven hips with O A, one hip with lesions of Legg-Calve-Perthe's disease, one with pseudarthrosis of the femoral neck and one infected fracture

Pre- and post-operative comparison of passive movement showed that this increased to a much greater extent than active movement Only a small number of patients had reduced or unchanged passive movement

Generally speaking, the operation resulted in an increased passive and active range of movement of the hip, and this was independent of the type of hip disease

Assessment according to age The patients were divided into three groups, as already mentioned, but in this case the number of operated hips is recorded *1st group* (9 hips) The active motion index increased in eight and decreased in one hip (average pre-op 27 8, post-op 42 2) *2nd group* (30 hips) The index increased in 23 and decreased in seven hips (average pre op 29 4, post-op 41 7) *3rd group* (9 hips) The index increased in seven and decreased in two hips (average pre-op 33 3, post-op 39 9)

Pre-operatively the smallest index was in the 1st group, and there was a progressive increase in the index in groups 2 and 3 Post-operatively in all groups there was an increase in the index average which was marked in the 1st group but less so in the 2nd and even less noticeable in the 3rd group

Study according to time elapsed since the operation The first group includes 14 hips, the second 14 and the third 20 (The patients were divided into three

groups as already mentioned, but in this case the number of operated hips is recorded)

The average index of active movement in the first group was pre operatively 28 7 and post operatively 41 4, in the second group it was 31 9 and 43 4 and in the third group 27 5 and 40 3 respectively Thus it is obvious that the period of the time elapsed since the operation does not influence the range of movement of the hip The improvement in range of movement, which was achieved with the operation, remained almost unchanged with the passing of time

Gait

The following factors make the influence of the operation on gait difficult to assess

1 Lesions of the contralateral hip (bilateral O A) may influence the gait with the passage of time
2 An operation may have to be performed on the contralateral hip
3 Operations on a lower limb may influence the gait Such cases were included in our series

At follow up in all cases limping was noted to a varying degree

The patients were divided into three groups according to the following parameters

Stick, crutches, wheelchair, distance, activity

1st group Patients with a slight limp and good stability of the hip, walking without help and coping well with daily activities *2nd group* Patients with an obvious limp and a degree of instability, walking with a stick, looking after themselves but unable to work *3rd group* Patients with a marked limp and great instability, walking with sticks or crutches or in a wheelchair, and having difficulties in looking after themselves

Assessment according to the type of disease Out of a total of 43 patients, 15 belonged to the first group (35 per cent), 14 to the second (33 per cent) and 14 to the third group (33 per cent)

A careful study of the results as regards walking in relation to the type of disease showed that the gait was unaffected by the particular disease for which the operation was performed

Assessment according to age When the patients were divided according to the classification given above, there were 15 in the first group (35 per cent), 14 in the second (33 per cent), and 14 in the third group (33 per cent)

A careful assessment of the results of the operation in relation to walking ability in the various age groups showed that there was a greater percentage of young patients in the 1st group (age 15–35, 57 per cent), while middle aged patients predominated in the 2nd group (age 35–55, 39 per cent) and there were more older patients in the 3rd group (age 55 and over, 50 per cent) Thus the walking ability was worse in the older patients

Assessment according to time elapsed since the operation Division of the patients according to the same classification of walking ability showed that 15 patients belonged to the 1st group (35 per cent), 14 to the second (33 per cent) and 14 to the third group (33 per cent)

A careful study of the results of the operation as regards gait (with reference to the period of time elapsed since the operation) showed that the number of patients in the 1st group decreased with the passage of time, whereas the number of patients in the second group increased, and the number in the third group remained stable Thus, the longer the period of time since the operation the poorer the walking ability (The patients pass from the first group to the second)

Personal opinion of the patients

The opinion of the patient should be seriously considered in the general as

sessment of the operation results The follow-up showed that improvement in pain, regardless of the other results, was the main reason for satisfaction on the part of the patients The patients were divided into four groups Extremely satisfied 31 (71 per cent) Satisfied 4 (9 per cent) In doubt about the results 5 (12 per cent) Not satisfied 3 (7 per cent)

DISCUSSION

Resection of the femoral head and neck proved useful in the hands of the orthopaedic surgeon as a method of treatment for diseases of the hip This was especially true in cases of unsuccessful total arthroplasties

Pain was found to decrease in a large number of the patients (72 per cent) It was not clear whether the nature of the disease had any bearing on the results of the operation as regards pain As to the influence of the age of the patients on pain, it was found that there were a considerable number of patients in the first group (i e patients who underwent surgery when young), who were without pain The majority of patients with mild pain were in the second and third groups (i e of middle and advanced age) At follow-up there were very few patients with severe pain and all were amongst those most recently operated The number of patients with medium or slight pain seemed to be unrelated to the period of time elapsed since the operation There was a slight increase in the number of patients with no pain, with the passing of time

The range of movement was generally improved by the operation Passive movements were almost certainly improved and also active movements in a considerable number of patients (79 per cent) Hip mobility increased and this was not related to the nature of the disease but to the patient's age Greater improvement was noted in young patients, it was less marked in middle-aged patients and even less noticeable in older patients

Improvement in post-operative active hip movements remained constant with the passing of time Walking with a degree of limping was always present but this improved because of the decrease in pain

The main disadvantages of this method are an unstable joint and a shortened limb, which result in a difficult gait These are counter-balanced by improvement in pain and hip movement

The results of the operation as regards gait did not seem to be related to the nature of the disease, but to the patient's age, especially in the younger age group

ACKNOWLEDGMENT

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Acta orthop scand 47 329-334 1976

LOWER EXTREMITY AMPUTATIONS IN THE COUNTY OF AALBORG 1961–1971

Population Study and Follow-up

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All lower extremity amputations in the county of Aalborg Denmark during the period 1961–1971 were analysed During this 10-year period the amputation rate did not increase Those requiring amputation were predominantly arteriosclerotics followed by diabetics The diabetics underwent amputation 3 years younger on average than the arteriosclerotics but it was more often possible to preserve the knee in diabetics There was a far higher rate of successful prosthetic fitting among patients in whom the knee had been preserved Despite a high mortality also beyond the first postoperative months prosthetic fitting was of such psychological and social value that every effort should be made to ambulate the patients The majority could be looked after in their homes This was the most positive finding in the present study

Key words leg amputation follow up incidence life expectancy, peripheral vascular diseases prosthetics

Accepted 6 i 76

In recent years there has been an increasing frequency of lower extremity amputations, with serious consequences for the patients and society at large In the county of Uppsala Sweden Hierton & James (1973) found the frequency to increase during the period 1947 to 1969 Alffram & Holmquist (1961) and Hansson (1964) have carried out population studies among lower extremity amputees in two large Swedish towns, Malmo and Gothenburg

To assess the situation in a Danish district the author studied all lower extremity amputations in the county of Aalborg Denmark, during the period 1961–1971, analysing the operative indication and level, the patient's age, and the survival time In the case of the survivors the social conditions were investigated

MATERIAL

In 1961 the county of Aalborg had a population of 240 000 and in 1971 it was 260 000 with a large proportion in the rural districts In Denmark as a whole the urban rural ratio is 2 1 in the county of Aalborg it is 1 1 1

The amputations had been performed in two large hospitals in Aalborg in one smaller orthopaedic hospital in Aalborg and in five small hospitals in the county Twenty two patients had the amputations in orthopaedic units outside the county of Aalborg.

The below knee amputations included amputations between the ankle and knee and one Syme amputation (diabetes) but no partial foot amputations whereas in the group of

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DISCUSSION

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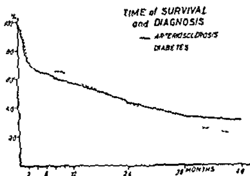


Figure 2 Survival and diagnosis

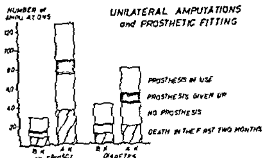


Figure 3 Unilateral amputations and prosthetic fitting Prosthesis in use/given up refers to results taken from case reports

Mortality

The mortality after 1 2 years (Figure 2) appears to have been the same in the group of diabetics as in the arteriosclerotics about 40–60 per cent but it must be noted that the diabetics were 3 years younger at the time of amputation and at the end of 4 years they had a lower survival rate

Prosthetic fitting

In the surgical unit where the amputation was carried out the suitability of the patient for prosthetic fitting was assessed and thereafter about 60 per cent of the patients who survived the operation were referred to a limb fitting centre

In relation to the amputation of the first leg 64 out of 312 patients died Of the surviving 248 patients 74 were considered unsuited for wearing a prosthesis Fifty three below knee prostheses and 118 above knee prostheses (primary prostheses) were supplied

Table 2 gives the supply of prostheses to unilateral amputees (corrected for re amputations)

During the training period one B/K and nine A/K amputees gave up using the prosthesis and later three B/K and 15 A/K gave up Thus four out of 53 B/K and 24 out of 118 A/K stopped using their prostheses All those who gave up were of the arteriosclerotic or diabetic groups. These figures were found on perusal of the case records as so far the patients had not been systematically followed up Presumably more than 24 have given up using above knee prostheses Figure 3 sets out the final result according to the case records

Only a few patients over 75 years had been fitted with prostheses (Figure 4) Out of 181 prostheses 116 were worn for more than 6 months (64 per cent)

An average of 17 7 weeks elapsed from the time of amputation until walking on a prosthesis was established in the case of the below knee amputees and in the above knee amputees it was 19.5 weeks

Social situation

Two thirds of the surviving patients with vascular disease were discharged to their homes 161 out of 249 Thirty nine were transferred to old age homes and 49 to nursing homes It was

Table 2 Unilateral amputation survival and prosthetic fitting

	Deaths	No prosthesis	+ prosthesis
B/K			
vascular	14	13	31
non vasc		2	12
A K			
vascular	49	67	105
non vasc	2	6	13



Figure 4 Age and prosthesis

Table 1 Diagnosis and level

	Below knee	Re-amp	Above knee	
Arteriosel	33	8	142	175
Diabetes	56	3	95	151
Trauma	11		18	29
Tumour	2		7	9
Other	2	1	6	8
	104		268	372

Arteriosel 19 % → 14 % below knee
Diabetes 37 % → 35 % below knee

above knee amputations there were two through-knee amputations (diabetes and tumour) and four exarticulations of the hip (malignant tumours)

Incidence

A total of 372 amputations were performed on 321 patients, all causes included This means an amputation rate of 14 9 per 100 000 of the population per annum Out of this number, 326 amputations on 277 patients were for peripheral vascular diseases (Table 1), giving an amputation rate for this category of 13 1 per 100 000 of the population There had been no increase in the rate in the course of the decade studied

Diagnosis age and level

The diagnosis in 175 amputations was arteriosclerosis and in 151 it was diabetic vasculopathy, 29 amputations followed trauma, 9 were because of tumours, and there were 8 for other reasons The arteriosclerotic group also included 14 patients who had had an operation for vascular disease or for embolism

Figure 1 gives the age distribution at amputation for patients with vasculopathy The patients with tumours averaged 30 1 years of age (5–71 years), the patients who had sustained trauma 50 2 years (8–83 years) The mean age at amputation for the diabetics was 68 6 years, whereas for the arteriosclerotics it was 71 6 years

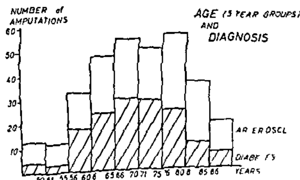


Figure 1 Age at amputation for patients with peripheral vascular disease

As already mentioned the analysis comprised eight surgical units during a period of 10 years There had been no attempt made to standardize the surgical technique or the indications for the level of amputation The only common feature was that the symptoms and signs before amputation were pain and/or gangrene (threatening or manifest)

In amputations on patients with vascular disease the surgically safe level had been preferred the majority being high amputations 237 (73 per cent) above knee and 89 (27 per cent) below knee (Table 1) In 35 per cent of the diabetics and in 14 per cent of the arteriosclerotics the knee was preserved

There had been no preoperative measurement of temperature, no thermography, or Xenon 133 studies, and immediate postoperative prosthetic fitting had not been carried out

Healing and complications

The mean healing time of the amputation stump was the same for diabetics and arteriosclerotics about 5 weeks (2–14 weeks)

Local complications were equally common for diabetics and arteriosclerotics 25 per cent in all (including all minor, superficial infections)

The complications were as follows

	Arterio scl	Diabetes	B/K	A/K*
Superficial infection	9	5	8	6
Deep infection	2	8	1	9
Necrosis	21	25	25	21
Exposed bone	7	3	2	8

* B/K = below knee A/K = above knee

The least number of complications occurred after high amputations 19 per cent after above knee amputations and 42 per cent after below knee amputations As a result 12 per cent of the patients having below knee amputations had to have re amputations above the knee whereas only 7 per cent of the patients having above knee amputations required re amputations higher up Local revisions were carried out in 8 per cent

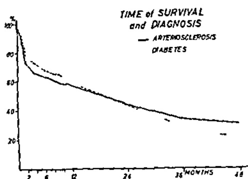


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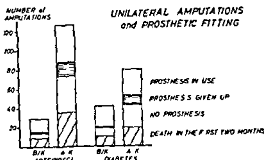


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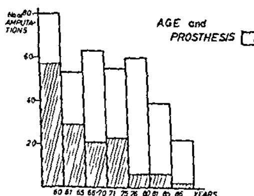


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Incidence

A total of 372 amputations were performed on 321 patients all causes included This means an amputation rate of 14 9 per 100 000 of the population per annum Out of this number 320 amputations on 277 patients were for peripheral vascular diseases (Table 1) giving an amputation rate for this category of 13 1 per 100 000 of the population There had been no increase in the rate in the course of the decade studied

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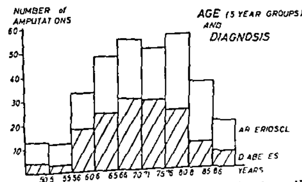


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Table 3 Amputations in vascular diseases age level and survival

	Number of amputations		Average age at amputation		Level of amputations No of amputations			Per cent alive one year after amputation	
	artscl	diab	artscl years	diab	B/K	T/K	A/K	artscl	diab
Hierton & James (1973)	38	56	76	72	55	–	38	40	60
Hansson (1964)	93	143	72	69	84	–	112	(45–55)	
Alffram & Holmquist (1961)	64	61	69	69	87	–	60	(60–55)	
Persson & Sundén (1971)	89	54	–	–	–	–	–	54	32
Lindahl & Bolund (1969)	109	74	70		5	14	76	–	–
Chilvers et al (1971)	58	17	66		53	22		–	–
Tibell (onset of symptoms) (1971) ♂	–	–	63	68	–	–	–	–	–
♀			69	76		–	–	–	–
Present study	175	151	72	69	88	1	237	53	60

Artscl = arteriosclerosis Diab = diabetes
B/K — below knee T/K = through knee
A/K — above knee

the amputation level during the decade of the present study

We are dealing with a *category of patients at risk* and more than one operation within a short time should be avoided However, owing to *the desire to* preserve as much as possible *of* the extremity, the risk of having to do secondary surgery must often be accepted Hierton & James (1973) and Green et al (1972) found a higher complication *rate after below* knee amputations The same was found in our material in which the re amputation *rate was* 6 6 per cent and the revision rate 8 5 per cent Persson & Sunden (1971) reported a better healing tendency in diabetics than in arteriosclerotics, *but* we found no difference

Our *mortality* corresponds largely to that reported by others

Prosthetic fitting in many series is about 50 *per cent* for patients over 60 65 years (*Berlelsen & Ronn* 1960, Alffram & Holmquist 1961, McKenzie 1953) Only about 25 per cent of the unilateral above-knee amputees *are fitted* with prostheses (Hierton & James 1973) In our material 47 per cent of the unilateral above knee amputees had been *fitted* with prostheses, or 59 per cent of the patients who survived the operation However, about one quarter of the fitted prostheses were not worn Sixty-four per cent of all unilateral below knee amputees were fitted with prostheses, or 77 per cent of those who survived the operation Among the bilateral amputees this rate was lower

A decrease in *the use of the* prosthesis occurs in a few months McKenzie de-*fined the* ~~ "
if it is wo
ing to thi
limb fitting *in* this study was successful

Discharge from hospital to full nursing care may become very expensive, but the *more patients* that can be discharged to their homes or to institutions with moderate nursing *care, the less the* expense Hansson (1961) reported that 1 year *after amputation* at the age of 60, 108 *patients* were alive, and of them 78 were in *nursing* institutions In Bergen, Norway, Kinge (1971) found that two thirds of the *survivors* were in nursing institutions In our material one third (88 out of 249) were discharged to old age homes or nursing homes

the above-knee amputees in particular who entered institutions Out of 45 patients without vasculopathy four died, eight were admitted to old age homes, and 33 were discharged to their own homes

Bilateral amputations

During the study period 51 persons had bilateral amputations, and 10 had previously undergone amputation of the contralateral leg Thus, the material includes 61 bilateral amputees, viz, 37 diabetics, 22 arteriosclerotics and two amputated after trauma

The interval between amputations averaged 12 months for patients with *peripheral vascular* disease Thirty-five had bilateral above-knee amputation and nine bilateral below-knee amputation Ten of the 61 patients died within 2 months of the second leg amputation Primarily 37 were discharged to their homes, 12 to old age homes, and 12 to nursing homes Five of the nine bilateral below-knee amputees learnt to walk This applied to one out of 35 bilateral above-knee amputees and to four out of 17 with one A/K and one B/K amputation

FOLLOW-UP

At follow-up 62 out of the 321 patients were alive, 3–13 years after the amputation Only 41 out of 272 patients (15 per cent) with vascular disease were alive, whereas 15 out of 25 patients with post-trauma amputation and five with amputation for tumour were alive Twenty-six of the 41 survivors with vascular disease were wearing prostheses, and of them 16 required help putting it on To be able to walk 19 had to use a stick at all times, whereas six used a stick only out of doors One used a walker

Amputation level/stick in 54 unilateral amputees

	No stick	Stick out of doors	Stick always required	No ambulation
B/K	9	2	10	2
A/K	8	4	15	4

Out of eight bilateral amputees one was able to walk on two below knee prostheses without using a stick

Phantom pain was *present* in 53 out of the 62 patients, but was severe in only three Twenty five patients had local stump pain, and one had *recurrent infection*

There were *no other complaints*

DISCUSSION

The increase in the amputation rate which has been observed elsewhere had occurred in this county before the present study period The amputation rate may depend upon the attitude of the hospitals and upon the geographic background In Malmo the rate was about 7 1 per 100,000 from 1949–1958, whereas Gothenburg exhibited an increase from 6 to 17 during the period 1947–1962 The county of Uppsala had 17 in 1967–1969, and Lund had 20 The latter two are mixed urban-rural districts and correspond more closely to ours (Alffram & Holmquist 1961, Hansson 1964, Hierton & James 1973, Persson & Sunden 1971)

In two previous Danish series (Lindal & Bolund 1969, Kolind Sorensen 1974) arteriosclerosis has predominated among patients with peripheral vascular diseases, just as in the present study The same finding was made by Chilvers in London in 1971 (Chilvers et al 1971) In the two Swedish analyses diabetes was the predominating diagnosis (Hansson 1964, Hierton & James 1973). Tibell (1971), in an analysis of peripheral arterial insufficiency, found a falling ratio diabetes arteriosclerosis in the course of time, so that they became more equal (Table 3)

During recent years it has been possible to achieve a higher proportion of below-knee amputations Within a comparatively short period of time (1953 1963 compared with 1964 1968) Sarmiento et al (1970) were able to alter the percentage of above knee amputations from 69 to 17, without using a new technique Persson & Sundén (1971) have developed a special new technique for below-knee amputations (sagittal) which has afforded a higher frequency of primary healing There was no change in

Acta orthop scand 47, 335–344, 1976

STRESS RADIOGRAPHICAL MEASUREMENT OF THE ANTEROPOSTERIOR, MEDIAL AND LATERAL STABILITY OF THE KNEE JOINT

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A hydraulically operated machine for applying well defined forces to the knee joint is described. The measurement of anteroposterior as well as lateral and medial stability in the knee joint is based upon roentgenograms exposed while the forces are being exerted on the patient. The advantage of the radiological measuring method over methods using external measurements is the elimination of inaccuracies due to displacements of the soft tissues of the limb. The accuracy was evaluated by test/retest examination of 50 healthy subjects. The radiographs were measured at random after cessation of examinations in the gonylaxometer. The accuracy is ± 1.2 mm for medial/lateral, ± 2.4 mm for drawer sign. Diagnostically the difference between the two knees must exceed 2.0 mm (collateral instability) or 3.1 mm (drawer) to exceed standard values. The standard values for the different ligament laxities are given. The applied force to be used for evaluation of medial/lateral stability is recommended to be 9 kg, and for anteroposterior stability between 20 and 30 kg.

Key words: gonylaxometry, knee ligament stability, drawer sign, collateral knee ligament laxity, radiological measurement

Accepted 20 xii 75

A method for the exact measurement of ligament stability in the knee joint would be of clinical importance from the diagnostic point of view as well as from the desire to introduce measurement of stability either pre- and postoperatively, or before and after conservative treatment of ligament ruptures in the knee joints. A measurable criterion of assessment would be of definite value in supplementing the patient's subjective assessment as well as the doctor's clinical (subjective) assessment which have so far characterized all analyses of therapeutic results.

The author has designed a machine and revised the method of measurement on the roentgen films in an endeavour to create a method, as exact and reproducible as possible, for measuring not only medial and anterior, but also lateral and posterior instability in the knee joint.

Conclusion

Now that the mean lifetime appears to have reached a peak, the number of amputations for peripheral vascular diseases would be expected to have become fairly stable, possibly with a slightly rising tendency

Since anaesthetic facilities have been so extensively developed, also in small hospitals, the risk connected with anaesthesia has been essentially reduced, and the risk which was previously involved in having repeated anaesthesias must be considerably less Thus, a lower amputation may be ventured, although it involves the risk of re-amputation

The present analysis showed Patients in whom the knee has been preserved have a far greater chance of being fitted with a prosthesis and are most likely to go on wearing it Patients over 75 years of age can seldom be fitted with prostheses The prosthetic fitting should be done as soon as possible If the patients can be ambulated, they are far more likely to be able to return to the environment from which they came, and thus expensive care in nursing institutions can be avoided Moreover, it is of the utmost psychological value to the patients to be able to return to their own environment

This study showed that patients amputated because of vasculopathy have a shorter survival time and that those patients who live longer are not such a burden on society as might be feared

ACKNOWLEDGEMENTS

Aided by the Medical Research Foundation for North Jutland For computer calculations thanks are due to C J van der Reeke and J Østergaard *professional engineers*

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Acta orthop scand 47 335-344 1976

STRESS RADIOGRAPHICAL MEASUREMENT OF THE ANTEROPOSTERIOR, MEDIAL AND LATERAL STABILITY OF THE KNEE JOINT

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Key words gonylaxometry, knee ligament stability drawer *sign* collateral knee ligament laxity radiological measurement

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The author has designed a machine and revised the method of measurement on the roentgen films in an endeavour to create a method as exact and reproducible as possible, for measuring not only medial and anterior, but also lateral and posterior instability in the knee joint

METHOD

Measuring apparatus

The apparatus is called the gonylaxometer It operates in conjunction with a roentgen tube *suspended in the ceiling and which may be* lowered to 60 cm above floor level It is built up over a horizontal steel trolley (2 × 1 m) with a central swivel (Figure 1) This frame supports a seat for the patient (posteriorly) a control panel (anteriorly) containing the hydraulic mechanism measuring and operating apparatus as well as slides and pistons to act upon the patient s lower limbs The seat floor, and slides are furnished with fasteners

The steel frame has four swivelling ball wheels which make the machine movable even in a small space Centrally there is a swivel base whose axis is midway between the patient s lower legs and knees through the middle of the sagittal cassette holder (Figure 2) During the radiography the apparatus may be turned on this axis when changing between views of the two knees from the lateral aspect obviating any *need for moving the roentgen tube The swivel* base may be raised and lowered manually

Between the control panel and the chair the steel frame is lined with aluminium flooring Its central part where the patient s feet rest during *radiography with knee joints flexed to 90°*, can be raised and lowered to adapt to the leg length of the patient

Posteriorly on the frame there is an upholstered seat for the patient with a back that may be shifted in the anteroposterior direction in relation to the seat The seat is raised and lowered by a pedal operated hydraulic cylinder (dental chair) to allow adjustment for different leg lengths and the right degree of flexion in the knee The entire seat can be shifted anteroposteriorly It may be rotated 90° to both sides on a vertical axis Anteriorly on the seat the thighs are placed into cup shaped metal supports

The control panel holds the hydraulic mechanism consisting of an oil reservoir and an electrically operated pump three cylinders a

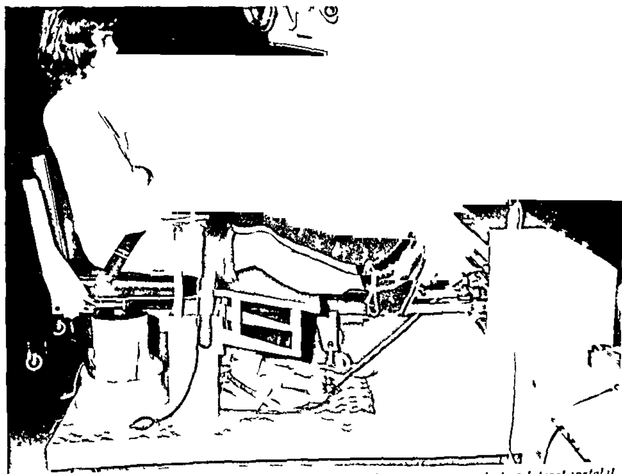


Figure 1 Gonylaxometer lateral view Patient in position for measuring medial or lateral instability Note the cassette holder in position under the patient s knees

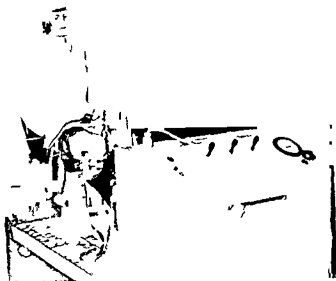


Figure 2 Gonylaxometer Patient in position for measuring anteroposterior instability Note sagittal cassette holder between the patient s knees Floor elevated to adapt to the length of the patient s legs

reducing valve for rough control and a reducing valve for fine control of the pressure The valve for rough control of the pressure, which can regulate the pressure between 0 and 200 kg is sealed after the required force has been fixed such that it permits pressure variations in a range from 0 to 30 kg Variations within this range are made by means of the other valve on a manually operated screw connected with a manometer mounted anteriorly on the panel (on the right in Figure 2) The movement of the cylinders is operated by the three handles an teriorly on the panel The middle handle oper ates the cylinder which exerts anteroposterior traction and pressure on the head of the tibia in the 90° flexed knee (anterior and posterior drawer sign—Figure 2) The two outermost handles operate the adduction and abduction forces (Figure 1)

The connection to the patient s knees during drawer manoeuvre is via a 65 cm long piston shaft which is fastened to the upper part of the lower leg by a padded canvas cuff The other two cylinders each operate a slide with ball bearings on steel rails in the panel Each slide may be shifted medially and laterally and carries fastening gear for the feet for use in abduction and adduction manoeuvres with a slightly flexed knee joint (160° position) The fastening gear consists of laced boots mounted on a plate on a steel arm which can be shifted by a telescope system to suit varying lower leg lengths Padded canvas straps for fastening the proximal part of the thigh, and inflatable cuffs for fastening the more distal part of the thigh are used The latter two cuff systems are fixed around the metal thigh rests

To obtain lateral views of the 90° flexed knees, a casette holder (for 24 × 30 cm films) is placed sagittally between the patient s knees (Figure 2) For adduction and abduction expo sures a casette holder is placed beneath the knees (for 30 × 40 cm films) (Figure 1)

Procedure

Measurements are made in two positions (a) In measurements of abduction and adduction laxity (medial and lateral stability, respective ly) the legs are flexed 20° at the knee joint The exposure in the AP projection is made of both knees at the same time The initial position in which the knees are unloaded and feel relaxed and the feet are 5° externally rotated in relation to the normal anatomical position is called "neutral position 160°" (b) In measurements of anteroposterior stability the legs are flexed 90° at the knee joints The exposure in the lateromedial projection is made of each knee separately The initial position with the foot resting on the floor of the machine and with the apex of the patella the tibial tuberosity and the second metatarsal bone in a vertical plane through the tibial axis is called "neutral posi tion 90°" The second metatarsal bone points forward in the longitudinal direction of the machine i e in the direction of traction

The first exposure is made in the position

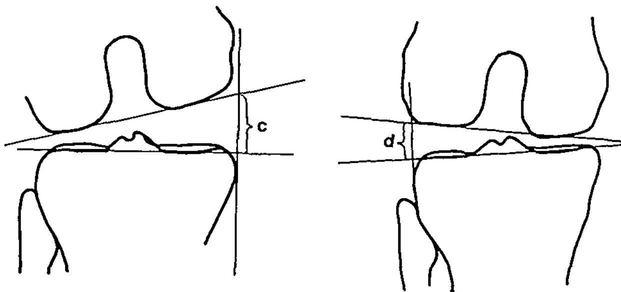


Figure 3 Measurement of medial looseness distance c and lateral looseness d on the AP radiograph

160° With a goniometer a measurement is made from the greater trochanter to the lateral *femoral epicondyle* (vertex) and lateral malleolus The large cassette holder which forms an angle of 10° with the horizontal plane is mounted A film is exposed while abducting both lower legs each being subjected to a force of (normally) 9 kg followed by a film with simultaneous adduction of both lower legs (force normally 9 kg)

Thereafter the patient is fastened in neutral position 90° and a lateral view is exposed of the unloaded knee joint The roentgen tube is adjusted to be at right angles to the now sagittally placed film cassette holder midway between the patient s knees The direction of the beam is lateromedial The thigh cuffs are inflated prior to each exposure to about 300–350 mmHg but are deflated between each exposure to allow circulation in the lower limbs

When exposures of the other knee are started the gonylaxometer is turned 180° on its central swivel foot so that the roentgen tube need not be moved All forces upon the joint are kept below the pain limit in healthy subjects (i e within the above mentioned forces) to avoid damage to the ligaments Control measurements of the hydraulic force (checking the manometer scale) are done for each 10 subjects The procedure takes 1 hour per subject

Measuring technique on the film

On the roentgen films the distances between the bony components of the joint are measured Rupture of a ligament manifests itself on the film as an increased distance between the various bones Comparison may be made with the patient s uninvolved knee or with standard values (see below)

The measurements on the radiographs are carried out by means of a Vernier scale along certain lines the radiographs being placed on a horizontal viewing box, the distances measured are illustrated in Figures 3 to 5 Distance c on Figure 3 represents medial stability (or looseness) distance d lateral stability Distance e (Figure 4) is measured on a baseline through the highest anterior and posterior points of the medial tibial condyle cut off between the tangents of the anterior point of the lateral femoral condyle and the posterior point of the lateral tibial condyle (exactly where the posterior arch of the lateral tibial intercondylar tubercle joins the posterior contour of this condyle) Distance f is the analogous distance cut off on the same baseline by analogous tangents of the *medial* femoral and tibial condyles While c and d represent distances measured when stress is applied to the knee e and f are measured on the lateral radiograph when the knee is not acted upon by any force When measured on a radiograph exposed during traction on the upper part of the tibia the corresponding distances are called g when connected with the lateral condyles and h when connected with the medial ones When exposed during application of a pushing force the analogous distances are called i and j (greater than e and f) As is seen from Figure 5 the anterior displacement of the lateral tibial condyle can be expressed as (e g) and analogously the anterior displacement of the medial tibial condyle can be expressed as (f–h) Posterior displacement of the lateral condyle

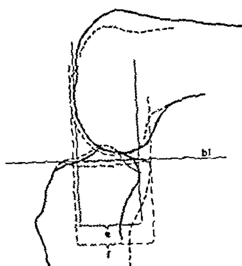


Figure 4 Measurements on the lateral radiograph in neutral 90° flexed position No forces applied Unbroken lines Lateral condyles Broken lines medial condyles bl base line e distance cut off on bl by tangents to anterior point of lateral femoral condyle and posterior point of lateral tibial condyle f distance cut off on bl by tangents to the medial condyles The lateral tibial condyle is identified by the form of the lateral tubercle (two arches an anterior and a lower posterior)

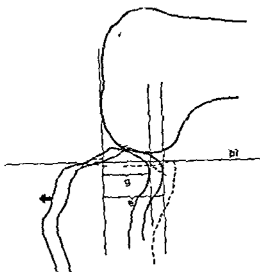


Figure 5 The movement of the lateral tibial condyle during traction (anterior drawer) Because of the anterior movement of the posterior point and its tangent the distance g measured during traction is smaller than distance e measured in the neutral position The anterior movement of the lateral tibial condyle is e–g

becomes (i–e) and of the medial condyle (j f) Total anterior displacement is expressed as the mean of the displacements of the two condyles

$$\frac{(e-g)+(f\ h)}{2}$$

$$\text{Posterior displacement} = \frac{(i-e)+(j\ f)}{2}$$

This measuring procedure takes half an hour

Material of healthy controls

Fifty normal subjects 25 females and 25 males were examined and the results of the measurements were used for assessing the accuracy of the method from one measurement to the other on the same subject These 50 persons had never had knee injuries, diseases or complaints and their knees were found to be normal on clinical examination Persons with a valgus deformity of the knee joints exceeding 10° were excluded as Thestrup Andersen (1955), in a material of persons with sound knees found the variation of the angle between the femur and the tibia in the frontal plane to be between 0 and 10° The length of the lower extremity was measured from the point of the greater trochanter to the point of the fibular malleolus Persons having a difference of more than 1½ cm in the lengths of the two legs were excluded All roentgenograms were normal. The age and sex distribution is shown in Table 1

A test/retest procedure was used After the measurement had been completed, the subject was released from the machine and walked

Table 1 Age and sex distribution

Age	Women Total	Women Group I	Women Group II	Men Total	Men Group I	Men Group II
20–30	22	15	7	18	13	5
31 52	3	2	1	7	4	3
20 52	25	17	8	25	17	8

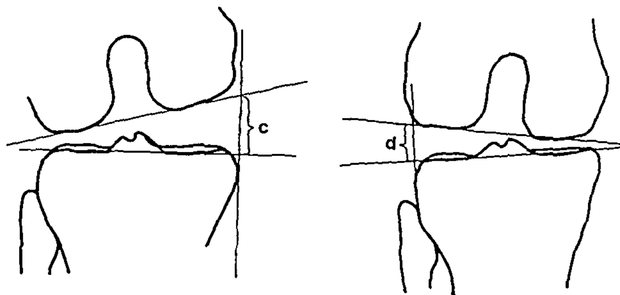


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Table 2 Standard values of knee stability in healthy subjects $\bar{x}_a \pm t_{2}a \times SD$ 17 ♂ + 17 ♀ Abduction — and adduction — force 9 kg pushing — and pulling — force 20 kg for 34 subjects $t_{2}a = 2\ 03$

Stability measured	Parameter		Standard values (mm) $\bar{x} \pm t_{2}a \times SD$	SD	Upper limit (right left) $\bar{x} + t_{2}a \times SD$	SD
Medial = valgus _ abduction	c	men	5 8 12 1	1 3	men & women	
		women	5 2 9 8	1 2	1 4	0 4
Lateral _ varus = adduction	d	both sexes	9 2 16 9	1 9	2 0	0 6
Anterior displacement:						
lateral condyle	e–g	both sexes	0 2 8 8	2 1	3 1	1 0
medial condyle	f h	both sexes	0 0–5 5	1 5	2 5	0 7
average	$\frac{(e-g)+(f\ h)}{2}$	both sexes	0 0–7 0	1 7	2 [illegible]	1 5
Posterior displacement						
lateral condyle	i–e	both sexes	0 2 6 0	1 4	2 9	0 8
medial condyle	j f	both sexes	0 0–3 4	0 8	1 9	0 5
average	$\frac{(i-e)+(j\ f)}{2}$	both sexes	0 8 4 1	0 8	1 9	0 8
Total AP displacement						
lateral condyle	i g	both sexes	3 1–12 0	2 2	3 1	0 9
medial condyle	j h	both sexes	0 2 7 5	1 8	3 1	0 9
average	$\frac{(i\ g)+(j\ h)}{2}$	both sexes	2 0–9 5	1 8	2 7	1 8

about in the room while the movable parts of the machine were returned to zero position. Thereafter, the subject underwent another measuring procedure. Each envelope containing one set of roentgenograms of this subject's knees was marked by a 5 digit code number. Thereafter, *the subject's* name and code numbers were filed in a sealed envelope. Measurement of the above-mentioned parameters on the roentgenograms were performed in randomized sequence and not until all subjects had undergone this test/retest procedure. After the measurements had been performed, the code with the name and 5 digit code numbers was broken, so that the duplicate examinations could be compared. No measurements were excluded from the analysis.

FINDINGS

Thirty-four persons (Group I, Table 1), 17 males and 17 females, were investigated by an abduction and adduction force of 9 kg and a pressure and traction force of 20 kg. A smaller group (Group II, Table 1) of eight females and eight males was investigated using other forces, in particular an abduction force of 18 kg and a traction force of 13 kg.

The accuracy of the measurement was assessed on the basis of the mutual difference between the duplicate determinations (the difference is designated d). SD' = standard deviation of difference $= \frac{1}{2} N \Sigma d^2$ *(Therkelsen 1968). In the* measurements of lateral and medial laxity, parameters c and d, the SD'_c = 0.56 mm, SD'_d = 0.59 mm, were calculated on the basis of measurements on 34 persons (force 9 kg). The inaccuracy of each measurement is then $\pm t_{\alpha} \times SD'$, i.e. less than ± 1.2 mm. For anterior displacement (parameter c–g lateral tibial condyle and f–h medial tibial condyle) and posterior displacement (i.e. lateral tibial condyle and j–f medial tibial condyle) and total anteroposterior displacement (i–g and j–h, respectively) the inaccuracy of measurement (determined with 95 per cent limits of confidence) was less than ± 2.4 mm.

When measuring a parameter in a person it can then be expected that a subsequent measurement of the same parameter in the same person (without intervening injury or treatment) will be within these limits. Thus, if a reduction of instability after operation or other treatment is to be demonstrated, it must be demanded at follow-up that the demonstrated reduction of the instability exceeds 1.2 mm. As far as the drawer sign is concerned, the reduction must exceed 2.4 mm.

If the abduction force of 18 kg is used in measuring medial stability (investigated in eight females and eight males) which the subjects feel as an uncomfortably strong force, the inaccuracy of the measurement is twice as great (± 2.2 mm). In the same subjects the accuracy of the measurement with a traction force of 13 kg in the anterior direction (drawer sign) is ± 2.4 mm, i.e. of the same magnitude as when using a traction force of 20 kg. In four of the male subjects a force of 30 kg demonstrated the same accuracy.

The standard values, defined as $\bar{x} \pm t_{2\alpha} \times SD$ of the various parameters, calculated on the basis of the measurements on the 34 persons (abduction and adduction force 9 kg and traction and *pressure force 20 kg) are shown in* Table 2. There is no difference between the standard values for the right and left leg. The table shows that the variation between subjects is very marked. Therefore, the difference between the measurements for the right and left leg on the same person was analysed and the standard values of this difference calculated. As far as abduction and adduction instability is concerned the difference between the two sides was normally less than 2.0 mm. With regard to anterior and posterior instability as well as total anteroposterior instability, this difference was less than 3.1 mm, for both condyles. Thus, lacking a preoperative measurement, the affected and the sound

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		women	5 2–9 8	1 2	1 4	0 4
Lateral = varus = adduction	d	both sexes	9 2–16 9	1 9	2 0	0 6
Anterior displacement						
lateral condyle	e–g	both sexes	0 2–8 8	2 1	3 1	1 0
medial condyle	f–h	both sexes	0 0 5 5	1 5	2 5	0 7
average	$\frac{(e-g)+(f\ h)}{2}$	both sexes	0 0–7 0	1 7	2 6	1 5
Posterior displacement						
lateral condyle	i–e	both sexes	0 2–6 0	1 4	2 9	0 8
medial condyle	j f	both sexes	0 0–3 4	0 8	1 9	0 5
average	$\frac{(i-e)+(j\ f)}{2}$	both sexes	0 8–4 1	0 8	1 9	0 8
Total AP displacement						
lateral condyle	i–g	both sexes	3 1–12 0	2 2	3 1	0 9
medial condyle	j–h	both sexes	0 2–7 5	1 8	3 1	0 9
average	$\frac{(i\ g)+(j\ h)}{2}$	both sexes	2 0–9 5	1 8	2 7	1 8

about in the room while the movable parts of the *machine were returned to zero* position Thereafter, the subject underwent another measuring procedure Each envelope containing one set of roentgenograms of this subject's knees was marked by a 5 digit code number Thereafter, the subject's name and code numbers were filed in a sealed envelope Measurement of the above-mentioned parameters on the roentgenograms were performed in randomized sequence and not until all subjects had undergone this test/retest procedure After the measurements had been performed, the code with the name and 5 digit code numbers was broken, so that the duplicate examinations could be compared No measurements were excluded from the analysis

FINDINGS

Thirty-four persons (Group I, Table 1), 17 males and 17 females, were investigated by an *abduction and adduction* force of 9 kg and a pressure and traction force of 20 kg A smaller group (Group II, Table 1) of eight females and eight males was investigated using other forces, in particular an abduction force of 18 kg and a traction force of 13 kg

The accuracy of the measurement was assessed on the basis of the *mutual* difference between the duplicate determinations (the difference is designated d) SD' = standard deviation of difference = ½ N Σ d' (Therkelsen 1968) In the measurements of lateral and medial laxity, parameters c and d, the SD'_c = 0 56 mm, SD'_d = 0 59 mm, were calculated on the basis of *measurements on 34* persons (force 9 kg) The inaccuracy of each measurement is then $\pm t_{2a} \times SD'$, i e less than ± 1 2 mm For anterior displacement (parameter e g lateral tibial condyle and f–h medial tibial condyle) and posterior displacement (i–e lateral tibial condyle and j–f medial tibial condyle) and total *anteroposterior* displacement (i–g and j–h, respectively) the inaccuracy of *measurement* (determined with 95 per cent limits of *confidence*) was less than ± 2 4 mm

When measuring a parameter in a person it can then be expected that a subsequent measurement of the same parameter in the same person (without intervening injury or treatment) will be within these limits Thus, if a reduction of instability after operation or other treatment is to be demonstrated, it must be demanded at follow-up that the demonstrated reduction of the instability exceeds 1 2 mm As far as the drawer sign is concerned, the reduction must exceed 2 4 *mm*

If the abduction force of 18 kg is used in measuring medial stability (investigated in eight females and eight males) which the subjects feel as an uncomfortably strong force, the inaccuracy of the measurement is twice as great (± 2 2 mm) In the same subjects the *accuracy of the measurement with a* traction force of 13 kg in the anterior direction (drawer sign) is ± 2 4 mm, i e of the same magnitude as when using a traction force of 20 kg In four of the male subjects a force of 30 kg demonstrated the same accuracy

The standard values, defined as $\bar{x} \pm t_{2a} \times SD$ *of the various parameters,* calculated on the basis of the measurements on the 34 persons (abduction and adduction force 9 kg and traction and pressure force 20 kg) are shown in Table 2 There is no difference between the standard values for the right and left leg The table shows that the variation *between subjects is very marked* Therefore, the difference between the measurements for the right and left leg on the same person was analysed and *the standard* values of this difference calculated As far as abduction and adduction instability is concerned the difference between the two sides was normally less than 2 0 mm With regard to anterior and posterior instability as well as total anteroposterior instability, this difference was *less than 3 1 mm,* for both condyles Thus, lacking a preoperative measurement, the affected and the sound

Table 2 Standard values of knee stability in healthy subjects $\bar{x}_n \pm t_{2a} \times SD$ 17 ♂ + 17 ♀ Abduction — and adduction — force 9 kg, pushing — and pulling — force 20 kg For 34 subjects $t_{2a} = 2\ 03$

Stability measured	Parameter	Standard values (mm) $\bar{x} \pm t_{2a} \times SD$		SD	Upper limit (right left) $\bar{x} + t_{2a} \times SD$	SD
Medial = valgus = abduction	c	men	5 8–12 1	1 3	men & women	
		women	5 2 9 8	1 2	1 4	0 4
Lateral = varus = adduction	d	both sexes	9 2–16 9	1 9	2 0	0 6
Anterior displacement						
lateral condyle	e–g	both sexes	0 2 8 8	2 1	3 1	1 0
medial condyle	f–h	both sexes	0 0–5 5	1 3	2 5	0 7
average	$\frac{(e-g)+(f\ h)}{2}$	both sexes	0 0–7 0	1 7	2 6	1 5
Posterior displacement						
lateral condyle	i–e	both sexes	0 2 6 0	1 4	2 9	0 8
medial condyle	j f	both sexes	0 0–3 4	0 8	1 9	0 5
average	$\frac{(i-e)+(j\ f)}{2}$	both sexes	0 8–4 1	0 8	1 9	0 8
Total AP displacement						
lateral condyle	i–g	both sexes	3 1–12 0	2 2	3 1	0 9
medial condyle	j–h	both sexes	0 2–7 5	1 8	3 1	0 9
average	$\frac{(i-g)+(j\ h)}{2}$	both sexes	2 0–9 5	1 8	2 7	1 8

leg may be compared postoperatively. A diagnostic evaluation before treatment can also best be done on the basis of the difference between the various parameters of the right and the left knee. If both knee joints are injured, the standard values of the parameter concerned must be used, but the wide biological variation of this value gives a less reliable diagnosis.

There is a statistically significant difference between women and men only in the case of parameter c ($P = 0.01$). For other parameters there is no significant difference between the sexes (neither for $P = 0.01$ nor for $P = 0.05$). Table 2, therefore, lists the standard values for women as well as for men only for parameter c and not for the other parameters. The values listed in the Table are the distances measured on the roentgenograms and are thus not corrected for the magnification (which is 1.1 or 10 per cent).

In addition, four subjects, two men and two women, characterized by hyperlaxity of the joints (knee extension greater than 195°, elbow extension greater than 190°, valgus deformity in the knees greater than 10° as well as hypermobility in the thumb) were examined. All the above mentioned gonylaxometer parameters and differences were within the normal limits (found for the 50 normal subjects).

DISCUSSION

The advantage of the radiological measuring method over those in which an instrument is placed on the outside of the lower limb is that it presents directly a distance between the bones of the joint, as a measure of the magnitude of instability. As the ligaments of the knee joint join bone to bone, the magnitude of this distance depends directly upon the state of the ligaments. The unknown inaccuracy in measurement introduced by soft tissue displacement is avoided. This inaccuracy also applies to Sprague & Asprey's photographic method (1965) in which marks are placed on the skin to indicate the direction of lines used in the measurement on the film. This inaccuracy can be read from the relatively low correlation coefficient which does not show a particularly good conformity between repeated measurements on the same persons ($r = 0.42$ to 0.82).

These displacements in the soft tissues cannot be eliminated by fixation. In the author's machine the patient's hip region is fixed in the seat by a strap, and both thighs are fixed by a canvas strap as well as a broad cuff inflated to a pressure of about 350 mmHg. In measuring, for example, anteroposterior instability with the knee flexed 90°, the sighting point marked on the lateral aspect of the knee shifts, nevertheless, 2–3 cm between the two extreme positions, indicating a displacement of the soft tissues of the thigh. This error is eliminated on the roentgen film.

An instrument designed by Klein (1962), constructed to measure medial and lateral instability in the extended or straight position of the leg, is said to be able to demonstrate isolated ruptures of the collateral ligaments of the knee. This is a technical as well as clinical error. Lateral or medial instability in the extended position is possible only in the case of rupture of a collateral ligament plus the anterolateral cruciate ligament or both cruciate ligaments plus the posterior capsule of the joint or in cases with loss of substance in the condyles (Hallén & Lindahl 1965, Palmer 1938). Accordingly, Klein's instrument can demonstrate only extensive, combined injuries. For the same reason, abduction and adduction instability is measured in the gonylaxometer with the leg in the 160° position in which instability due to an isolated injury to the collateral ligaments can be demonstrated,

as the other structures are relaxed The 2 3° to 2 6° abduction and adduction instability measured by Klein in extended normal knees may easily have been due solely to displacements of the soft tissues

The advantage of the hydraulic system acting upon the knee joint is the possibility of reproducing an examination of the same patient using exactly the same force Moreover, the machine ensures the same radiological projection

The author disagrees with Kennedy & Fowler (1971) regarding the landmarks they use for identifying the tibial and femoral condyles In a subsequent paper this will be demonstrated Confusion regarding the position of the posterior contours of the tibial condyles may explain why the anterior displacement found on traction in Kennedy & Fowler's material of normal knees was different from the present findings Kennedy & Fowler found anterior displacement to be the same for both tibial condyles, whereas in the present material there was a considerably greater anterior mobility of the lateral tibial condyle in normal knee joints up to 9 mm as compared with Kennedy & Fowler s 5 mm for both tibial condyles (cf Table 2) In the present study the anterior displacement of the medial condyle was found to be 5 5 mm

An abduction and adduction force of 9 kg has proved to be the most suitable, as it is of sufficient strength and is not too uncomfortable for the patients It, therefore affords the most accurate measurements as pain conditioned contractions of the muscles are avoided In examinations for the drawer sign a force of 20 to 30 kg is optimal

The measurement accuracy of the machine (± 1 2 mm for lateral and medial instability ± 2 4 mm for measuring anteroposterior instability) has proved to be quite adequate for the assessment of results of operations and other treatment, as it cannot be expected, in a biological material, to improve instabilities in the knee joint of a magnitude as slight as 1 2 mm by operation, for example Moreover, an instability which troubles the patient is empirically of a considerably greater magnitude

For diagnostic use, in acute injury to the knee as well as in chronic instability following prior, untreated injuries, the upper limits stated for the normal difference between the two knees (rather than the fairly wide standard values) have also proved to be very satisfactory The difference between the two knee joints has to exceed 2 0 mm to fall outside the standard values for lateral and medial instability and 3 1 mm for the drawer sign A comprehensive pathological material, measured and operated on, is being analysed at present

ACKNOWLEDGEMENTS

Aided by grants from the Danish Medical Research Council the Danish Council for Sports Research and the Foundation for the Handicapped

The apparatus was constructed in collaboration with the Welding Institute of The Academy of Technical Sciences, under the management of A Northeved and P Nordvang professional engineers

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Acta orthop scand 47 345–350 1976

THE SUBCHONDRAL BONE IN OSTEOARTHRITIS AND RHEUMATOID ARTHRITIS OF THE KNEE

A Histological and Microradiographical Study

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Specimens of the joint surfaces of the tibia from patients with OA and RA were examined for bone mineralization, bone formation, osteoid tissue and bone resorption. Judging from the appearance of the osteoblasts in OA the sclerotic changes are mainly focal with relatively little osteogenesis. No osteoclasia was seen in the sclerotic areas. Breakdown of the mineralized cartilage is followed by the development of cysts with highly cellular connective tissue with high osteoblastic activity and osteoclasia. Osteoid tissue is relatively sparse. The changes in RA are more diffuse with a more active osteoblastic activity and widespread zones of osteoid tissue as well as resorption by osteoclasts. It appears as if the increased uptake of ^{85}Sr in OA is more dependent on the occurrence of relatively inert osteosclerosis than on a rapid turnover of the bone tissue.

Key words: osteoarthritis, rheumatoid arthritis, knee joint, subchondral bone, microradiography

Accepted 11.xii.75

The disease process of osteoarthritis involves not only the cartilage but also the subchondral bone. Even at a very early stage of the disease, metabolic changes of the subchondral bone can be demonstrated as an increased uptake of radioactive strontium (Danielsson *et al.* 1963, Andersson *et al.* 1967). As the osteoarthritis advances, the uptake of Strontium becomes abnormally high in those areas where osteosclerosis is roentgenographically demonstrable. This may be due to a greater amount of bone in *these areas* or to an increased turnover *of mineral*. Isotope studies have shown that *osteoarthritis* is probably associated with an increased synthesis of bony tissue rather than a decreased resorption (Bauer & Smith 1969). As for the uptake of ^{85}Strontium in rheumatoid arthritis it has been shown to be high but less focal than in osteoarthritis (Holopainen & Rekonen 1966).

This paper concerns the histological and microradiographical evaluation of subchondral bone in bone formation and bone resorption, respectively, in osteoarthritis (OA) and in rheumatoid arthritis (RA). Special attention is directed to the occurrence of osteoid tissue, which

Financial support was obtained from Svenska Läkaresällskapets fonder, Herman Järnhardts stiftelse, Riksförbundet mot Reumatism and Ulla & Gustaf af Ugglas fond

as far as OA of the hip joint is concerned, has been studied by Batra & Charnley (1969).

MATERIAL AND METHODS

Specimens of the joint surfaces of the tibia were obtained from pieces of bone excised during various types of total arthroplasty of the knee (St Georg's sledge prosthesis, Geomedic's and Guepar) The material consisted of 16 patients with OA and 11 with RA Of the 16 patients with OA, all were operated upon unilaterally only, four with Geomedic's method (both condyles) and 12 with St Georg's (1 lateral condyle and 11 medial condyles) Of the 11 patients with RA, two were operated upon on both sides, giving a total of 13 knees from which specimens could be obtained from both condyles

The excised pieces of bone, consisting of the central parts of the respective condyles, were sawn into two sagittal slices The anterior part of the first slice was fixed in formalin and decalcified in formic acid and used for histological examination It was cut into 5–7 μ sections, which were stained with haematoxylin-eosin, van Gieson and Safranin-O The second slice was cut into at least three sections, which were fixed in formalin, dehydrated and embedded in methyl methacrylate without decalcification Sections 5 μ thick were cut with a bone microtome These sections were stained with Goldner stain (Schenk 1965) and examined for osteoid tissue Parts of the slice were embedded in methyl methacrylate, ground down to a thickness of 100 μ and used for microradiography The pictures were taken with a Philips diffraction tube using 20 kV and 30 mA at a focal distance of 30 cm and with an exposure time of 10 minutes The film used consisted of high resolution plates and the developer was a D 19 B



Figure 1 Mic... subchondral mineralized section, give subchondral bone

FINDINGS

The roentgenograms of the knee joints showed a varying degree of OA and RA The changes ranged from relatively mild unicondylar OA to severe bicondylar changes Also the roentgenograms of RA showed varying stages of RA, though mostly severe destruction with or without secondary OA

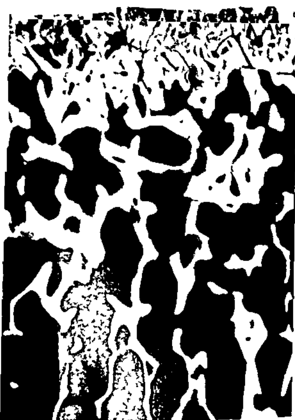


Figure 2 Microradiograph (×6 3) Osteoarthritis, sclerotic bone in the superficial layer under the denuded cartilage Transition to spongy bone of fairly normal appearance is abrupt

Osteoarthritis

The osteoarthritic changes of the cartilage varied from superficial fraying to

complete denudation The weightbearing parts of the cartilage exhibited the greatest changes whereas particularly on the anterior margin of the tibial condyle the thickness of the cartilage was still normal even in fairly advanced cases Clusters of chondrocytes were seen especially basally in the relatively intact cartilage Necrosis of the chondrocytes was common especially when the superficial layers of the cartilage had been destroyed Staining with Safranin O showed a considerable decrease in orthochromasia particularly in the transitional and columnar layers being less noticeable pericellularly and especially around the clusters Also in histologically relatively intact parts of the cartilage the uptake of the dye was decreased Sometimes the tidemark was double or multiple as has also been described by Green et al (1970) The borderline between the mineralized cartilage and the subchondral bone was very irregular and each tissue showed extensions which fitted in between one another as has been described by Stougård (1974) (Figure 1) The subchondral bone had a strong tendency to undergo sclerosis in the form of thickening and confluence of the trabeculae to form massive blocks of bone containing single vessel canals When the bone was completely denuded the surface layer exhibited necrotic osteocytes The severity of the sclerosis clearly varied with damage to the overlying cartilage When the cartilage was relatively intact the underlying trabeculae were of normal appearance The thinner the cartilage the more massive the sclerosis The sclerosis was clearly focal The sclerotic changes varied in depth from 500 3000 μ but were



Figure 3 Micrograph (× 9 6) Rheumatoid arthritis Bone showing signs of pronounced bone formation

often abruptly bordered by spongy bone of normal appearance (*Figure 2*) No microscopic fractures or nodular aggregates ("birds nests") (*Todd et al 1972*) were found in this spongy bone The trabeculae were mostly highly mineralized without appreciable signs of remodelling of the bone Where the OA was severe, it had locally broken through the mineralized cartilage, which otherwise appeared to be very resistant In such cases resorption cavities extending downwards from the surface and filled with granulation tissue were visible The spaces between the bone trabeculae contained fatty marrow, except where the trabeculae were sclerotic, here the tissue was fibromyxotic and poor in cells The resorption cysts contained highly cellular tissue

There were osteoblasts on the sclerotic trabeculae and to a lesser extent on the normal trabeculae The osteoblasts were invariably flattened, suggesting low activity (so called resting osteoblasts) Only in the resorption cavities (cysts) were the osteoblasts more active and protrudent The amount of osteoid tissue found in OA bone stained *ad modum* Goldner was small, but increased with the severity of the OA and was found particularly on trabeculae surrounding granulation tissue and in resorption cavities These cavities also contained osteoclasts which were hardly ever seen elsewhere New bone formation occurred inside the cysts

The specimens contained very few osteophytes, but where they were found they were seen to form on the remains of the mineralized cartilage, frequently with a persisting tidemark



Figure 4 (Microradiograph (× 9) Rheumatoid arthritis osteophytes on the old cartilage whose mineralized part is visible as an undulating line across the entire section

Rheumatoid arthritis

RA differed from OA in that the cartilage was damaged to a greater extent The cartilage often including the mineralized cartilage was resorbed by massive granulation tissue which often broke into the subchondral bone where it filled large cavities New bone formed in these cavities There were also islands of relatively intact cartilage which however did not stain orthochromatically with Safranin O The tendency of the bone trabeculae to undergo sclerosis was less than in OA Even when the cartilage had been completely destroyed the trabeculae were still of roughly normal thickness These trabeculae contained bone of a different degree of mineralization i e the bone tissue was in a state of remodelling (Figure 3) However some specimens of the knee with long standing RA showed secondary OA with sclerosis of the subchondral bone The bone marrow was to a large extent filled with highly cellular tissue which had replaced the normal fatty tissue Osteophytes were seen in a large number of preparations where they had the same appearance as in OA The osteophytes had formed on relatively preserved mineralized cartilage (Figure 4)



Figure 5 Microphotograph (× 49) Rheumatoid arthritis Goldner stain of non decalcified bone showing active osteogenesis around spongy cavity with granulation tissue The black zones denote osteoblasts + osteoid tissue

Osteogenesis was much more active than in OA Everywhere the bone trabeculae showed active osteoblasts standing on edge as well as abundant osteoclasts In sections stained *ad modum* Goldner osteoid layers were seen under these osteoblasts (Figure 5) These layers were relatively thick and were made up of 2–3 layers of collagen fibrils demonstrable by polarized light

DISCUSSION

Examination of specimens of the tibial condyle from patients with OA and RA showed that these diseases differ in the type of new bone formation in the subchondral bone of the knee In OA the changes consist of focal changes of the subchondral bone consisting mainly of relatively limited blocks of thick confluent trabeculae relatively abruptly outlined against more normal bone trabeculae The osteogenesis on the sclerotic trabeculae appears to be relatively slow judging from the appearance of the osteoblast No osteoclasts were seen in any of the sclerotic areas In those areas where the mineralized cartilage had been broken through cysts arose in the bone with highly cellular connective tissue and the trabeculae surrounding these cysts showed an appreciably increased osteoblastic activity in association with osteoclasia These cysts contained also newly formed cartilage and bone Osteoid

tissue was seen only in those areas afflicted by advanced OA

In RA there was a more diffuse change in the major part of the subchondral bone The trabeculae there were of relatively normal thickness but showed different degrees of mineralization There was strong osteoblastic activity as well as osteoclasia The amount of osteoid tissue was appreciably higher than in OA Judging from the present findings, in relation to those made in investigations with ^{85}Sr, the increase in the isotope uptake in OA can be ascribed to focal increases of the bone mass consisting of sclerotic areas without signs of bone resorption Not until OA is at an advanced stage does the histological picture show evidence of a quicker turnover with resorption cavities and active osteoblasts

The substantially increased uptake of ^{85}Sr in RA is reflected by the morphological picture with large areas with appreciably high activity of the osteoblasts and osteoclasts

Osteoid tissue occurs in both OA and RA, but to a greater extent in RA In OA, osteoid tissue occurs only in those areas where the OA is most advanced The occurrence of osteoid tissue may perhaps be explained by osteogenesis being too rapid for normally mineralized tissue to form

Lereim et al (1974) have shown that the subchondral bone is less hard than normal in the tibial condyles in both OA and in RA and that the decrease in hardness is equal in both diseases The histological picture does not offer any explanation as to why the decrease is equal in both diseases The subchondral bone in RA is clearly osteoporotic, while in OA the subchondral bone is focally sclerotic, but otherwise relatively normal The osteoarthritic bone has evidently undergone qualitative changes making it more brittle than normal bone

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Acta orthop scand 47 351–357, 1976

SEGMENTAL TIBIAL SHAFT FRACTURES

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A series of 54 cases with multiple fractures of the tibia is reported Sixty eight per cent of the group were pedestrians hit by a car Fifty two per cent were open fractures Osteosynthesis was performed in 33 cases, whereas 21 were treated conservatively Plate osteosynthesis was accomplished in 23 cases seven had intramedullary nailing and two were treated by Hoffmann's external fixation device Only one patient sustained a severe complication viz, deep wound infection and osteomyelitis however even this infection was transient All fractures healed except those sustained by two patients who died within 3 months these deaths were however, without any causal relationship to the osteosynthesis One patient had a traumatic vascular lesion concomitant with the fracture and his leg was amputated 3 days after the injury Another patient had his leg amputated 1 year after his accident in this case also because of injury to the vessels and nerves It was concluded from the present series that *segmental or multiple* tibial shaft fractures do not entail more *complications nor do they* exhibit a slower rate of union than simple *tibial shaft fractures if the treatment is individualized* and due consideration is given to the soft tissue injury

Key words fracture segmental fracture tibia

Accepted 10 xii 75

In spite of recent achievements in operative fracture treatment, tibial shaft fractures still present many problems, and the end results are not completely satisfactory The AO method for compression osteosynthesis generally considered to be the most suitable, has also met with some opponents who maintain that in transverse fractures of the tibial shaft this method ought not to be used (Bauer & Hulth 1973) or its use restricted (Karlstrom & Olerud 1973)

The importance of a sound policy as regards treatment of tibial shaft fractures is obvious, especially considering the high incidence of these fractures

The aim of the present study was to investigate the current treatment and the end results in a special type of tibial shaft fracture, viz, segmental or multiple fractures Publication of this paper was found justified because segmental fractures are rarely encountered, and very few authors have published materials of their own on the subject Furthermore, multiple tibial shaft fractures may, as mentioned later under the heading Discussion, involve a number of problems as regards vascularization of the ring fragment, and also as regards operative technique That multiple tibial shaft fractures are of current interest is clearly



Figure 1 Front view of a typical two level segmental fracture

demonstrated by these fractures being chosen for AO-documentation when the Scandinavian section of the AO-group was established

Segmental fractures can be defined as diaphyseal or even metaphyseal ring fractures in which the cancellous circumference of a tubular bone is fractured at two or more separate levels, thus forming intermediate ring fragments, but excluding butterfly fragmentation The intermediate fragment or fragments may well be comminuted, the decisive criterion for inclusion in the series was the presence of two or more definite fracture lines

MATERIAL

During the 5-year period 1968 1972 altogether 639 fractures of the shaft of the tibia were treated in adults (i e over 14 years at Ullevål Hospital Departments II and III Of these 54 (8 5 per cent) were segmental shaft fractures The number of tibial shaft fractures treated operatively by osteosynthesis was 302 (47 3 per cent) in the whole group as against 33 (61 1 per cent) of the segmental fractures

The observation period can be seen from Table 1 Approximately 70 per cent were observed for more than 6 months and all complicated cases were followed until the ultimate result was clear

Table 1 Observation period

Months	No	Per cent
< 3	8	14 8
3–5	8	14 8
6–12	8	14 8
> 12	30	55 6
Total	54	100 0

There was a slight preponderance of men in the age groups 15–24 and 25–44 otherwise the sex and age distributions were fairly even

Traffic injuries predominated as the cause of the injury (68 1 per cent), followed by industrial accidents (9 2 per cent) All traffic injuries were pedestrians hit by a car Concomitant and rather serious lesions were frequent (57 per cent) with head injuries topping the list (33 per cent)

The treatment given is shown in Table 2 Open fractures totalled 28 cases (51 9 per cent) and 14 of these fractures were operated Initially non operative treatment was generally preferred as demonstrated by the fact that 64 per cent of the patients with segmental tibial shaft fractures were treated by skeletal traction There was also a tendency for osteosynthesis to be used more frequently in closed rather than in open fractures (19 out of 26 as against 14 out of 28), but osteosynthesis was not considered contraindicated in open fractures if the soft tissue injury was minor

In the present series the majority of segmental tibial shaft fractures had a rather unfavourable location prognostically the lower fracture being located in the distal half of the tibia in 44 cases (81 5 per cent) Comminution of the intermediate fragment was found in 18 cases (33 3 per cent) Consequently the chances of a rapid and uncomplicated healing were slim in the present material (Table 3)

The rate of union will be seen from Table 4 Thirty two fractures (59 3 per cent) healed within 6 months Slow union i e healing after more than 6 months was found in 11 cases (20 4 per cent) and non union in only one patient Slow union or non union did not seem to have any causal relationship to operative or

non-operative treatment but on this point the material is not definitely conclusive because there are so few patients in each group

Operative and late complications are shown in Table 5 A serious complication occurred in one case only a patient sustained osteomyelitis of short duration possibly induced by the operation The infection healed with antibiotics without any revisional surgery being required.

Fat embolism was not seen in the present material One patient had his leg amputated shortly after admission because of vascular injury peripheral nerve injury and subsequent septicaemia A second patient was amputated one year after the injury, because of disturbed sensibility pes equinus and shortening of the leg

Minor complications such as superficial wound infection thrombophlebitis pressure sores from the plaster etc occurred in 11 cases (33 3 per cent) Open fractures had an overall complication rate which by far exceeded closed fractures but again the groups are small and chance factors may have influenced

Table 2 Treatment of segmental tibial shaft fractures

Method	Open fractures		Closed fractures	
Skeletal traction and plaster		14		7
Skeletal traction and osteosynthesis		6		9
Primary plate osteosynthesis		4		4
With plaster	1		–	
Without plaster	3		4	
Intramedullary nailing		2		5
Cerclage				1
Osteotaxis Dr Hoffmann s method)		2		–
Total		28		26

Table 3 Treatment related to site of fracture and comminution of intermediate fragment(s)

Method	Site of distal tibial fracture Proximal ½	Distal ½	Comminution of intermediate fragment(s)
Skeletal traction and plaster	5	16	4
Skeletal traction and osteosynthesis	4	11	5
Primary plate osteosynthesis	1	7	5
Intramedullary nailing	–	7	3
Cerclage	–	1	–
Osteotaxis (Dr Hoffmann s method)	–	2	1
Total	10	44	18

Table 4 Rate of union of segmental tibial shaft fractures

Time months	Open fractures	Closed fractures	Treatment Operative	Non operative
Less than 4	4	10	11	3
4 6	9	9	13	6
7 12	2	1	–	3
More than 12	6	2	5	3
No information	2	3	–	3
Slow union	8	3	5	6
Non union	1	–	–	1

Table 5 Complications of operative treatment of segmental tibial shaft fractures

Nature of complication	Open fractures	Closed fractures
Wound infection	3	–
Osteomyelitis	1	–
Haematoma/bleeding	–	2
Shortening of the leg	2	1
Thrombophlebitis	–	1
Pressure sore from the plaster	2	–
Comminution of fragment by intramedullary nailing	–	1
Total	8 (57 %)	5 (26 %)

Thirty-three fractures were operated *in toto*, 14 open and 19 closed

RESULTS

Assessment of clinical end results

The criteria for evaluation were

Full restitution No subjective complaints, full working capacity to the same extent as before the injury and/or no functional impairment In addition, no detectable disability at follow-up

Some functional impairment Any subjective complaints of joint stiffness, muscular atrophy or weakness or minor sequelae of any kind not, however, seriously incapacitating working ability or the function of the wounded extremity Verification of corresponding findings at the follow-up

Poor results Amputated limb or any other major sequelae leading to poor function

The clinical end results evaluated as above are presented in Table 6 In 29 cases the functional results were classified as quite satisfactory, the patients had no complaints, and full restitution was clearly achieved

Fourteen patients had some minor complaints, seven suffered from slight stiffness of the ankle five had a minor atrophy of the calf muscles, in no instance, however, exceeding 1 cm when measuring the maximum circumference of the leg All these five patients felt weakness of the leg, but managed to do their jobs without difficulties Two patients had an outward rotational displacement of the lower leg amounting to 5° and close on 10°, respectively, but neither of them wanted operative correction

The clinical results in the two amputees were poor, but the results could in our opinion, hardly be ascribed to therapeutic failures, they were consequent upon the serious injuries sustained

Information was lacking as regards four patients, they had moved to other districts and could not be traced.

Altogether 79 per cent of the patients treated had an acceptable outcome of their injury and the treatment received,

Table 6 Clinical results of treatment of 54 segmental tibial shaft fractures

Evaluation	No	Per cent
Full restitution	29	53 7
Some functional impairment	14	25 9
Amputation	2	3 7
No information	4	7 4
Total	49	90 7

Five patients (9 3 per cent) died from causes *which could not be ascribed to the osteosynthesis*

if the number of patients with some functional impairment is added to the group with highly satisfactory results

DISCUSSION

When undertaking the present study it was anticipated that segmental fracturing of the tibial shaft might involve special problems these fractures often being caused by serious and direct traumatic injury of the leg as would be the case for instance when a pedestrian is hit by a car It was obvious that accidents of this kind could entail serious soft tissue injury which might complicate surgical treatment and also delay bone union

Multiple fractures can also lead to a poor vascular supply of the intermediate fragment or fragments or even avascularization The same might result from intramedullary nailing if the ring fragment is twisted and thus deprived of nourishing vessels An avascular intermediate fragment totally separated from adjoining soft tissue was seen in one case in the present series it was replaced however and ultimately healed as a bone graft

Predominantly operative treatment of tibial shaft fractures meets with some opposition (Bauer & Hulth 1973 Karlstrom & Olerud 1973) although several recent reports claim favourable results (Tscherne et al 1967 Zimmermann 1967 Decoulx et al 1969 Zucman & Maurer 1970 Solheim & Bo 1973)

In the present series of 54 consecutive segmental tibial shaft fractures an initially non operative treatment was considered essential The high incidence of serious concomitant injuries (57 per cent) and the frequent serious soft tissue injuries in these patients are factors favouring a non surgical approach for at least 1 week after the injury Open fractures in our opinion should be even more cautiously treated until the serious risk of deep infection or osteomyelitis has subsided

In two level tibial shaft fractures intramedullary nailing is the method of choice if applicable because this procedure secures re alignment and usually yields rigid fixation of both fractures thereby enabling the patient to exercise his muscles and joints after a short immobilization period an essential part of the after treatment of fractures (Olerud & Karlstrom 1972) An additional and in fact essential benefit is that extensive skin incisions over the fracture are avoided in closed intramedullary nailing In some cases a two step intramedullary nailing may be advantageous (Zucman & Maurer 1969) a thin nail is used initially with no reaming or only very cautious reaming and later the nail is re



Figure 9 Segmental tibial shaft fracture treated by a thin intramedullary nail



Figure 3. Severe crush fracture of the tibial shaft after stabilization with Hoffmann's fixation device.

placed by a thicker one after more extensive reaming, when the fractures are somewhat consolidated. This procedure was used in four cases in this series.

In metaphysial fractures, however, intramedullary nailing is not used, and in this series AO internal fixation was preferred in such cases, sometimes with additional external fixation in plaster. This treatment was especially satisfactory in proximal metaphysial fractures, which usually heal within 6–8 weeks, and in which adverse reactions to plaster immobilization are consequently seldom encountered.

The present material was not suitable for evaluation of the important question as to whether primary or supplementary external fixation using plaster would influence future ankle movement.

In this series, irrigation of the wound with saline solution and local application of broad-spectrum antibiotics were recommended. Usually suction drainage of the wound was applied. Prophylactic systemic use of antibiotics was not considered justified.

Hoffmann's external fixation device was used in two patients in this series, and this procedure is considered to be the method of choice in fractures with associated severe soft tissue injury. This is illustrated by the following case.

Case report. A man aged 38 had his leg completely crushed in the middle third of the tibial shaft in a severe car accident. The vascular supply and innervation, however, remained intact. Hoffmann's equipment was applied in two



Figure 4. Same case after healing. A nondisabling lateral displacement of the distal fragment is present.

different planes One set loosened after 5 months and was removed the other was removed after an additional 3 months whereupon bone grafting was carried out through a dorso lateral incision and the leg was immobilized in plaster and ultimately the fracture healed

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Acta orthop scand 47, 358-360, 1976

ANEURYSMAL BONE CYST OF THE TALUS

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Aneurysmal bone cysts localized in the talus are extremely rare Such a case is described and the histological findings are analysed in relation to those in aneurysmal bone cysts in general The pathomechanism of the lesion is discussed

Key words aneurysmal bone cyst, talus, giant cells

Accepted 18 ii 76

Localized fibrocystic disease is a generic term for a group of nine lesions which have a number of features in common, but each of which is a distinct entity 1) Unicameral bone cyst, 2) fibrous dysplasia, 3) fibrous metaphyseal defect, 4) nonosteogenic fibroma, 5) aneurysmal bone cyst, 6) giant cell tumour, 7) osteoblastoma, 8) chondroblastoma and 9) chondromyxoid fibroma

All nine lesions are often referred to as bone lesions containing giant cells A radiolucent lesion (cyst) is the characteristic picture

The usual site for all these lesions is the long bones or the spine, but they can be discovered in many other parts of the human body However, in a review of the literature we have been unable to find more than one report describing a unicameral bone cyst localized in the talus (Ogden & Griswold 1972) There was also one report describing an alleged case of aneurysmal bone cyst in the talus (Buchs 1963), which actually was a giant cell tumour, and only one report of an authentic aneurysmal bone cyst in the talus (Slowick et al 1968)

Aneurysmal bone cyst is a benign lesion of bone, first described by Jaffe & Lichtenstein (1942). The lesion has been observed in many parts of the skeleton but occurs most often in the shafts of the long bones, and in the vertebral column

This paper presents one more case of aneurysmal bone cyst of the talus

CASE REPORT

R I, 30 year-old surveyor's assistant, no illness in previous history Three months before admission (September 1971) the patient noticed pain in the right foot mostly on the lateral aspect when he had been walking some distance in the pursuit of his work He ascribed this to a sprained ankle, but when the symptoms persisted he consulted a doctor An X ray revealed a cyst in the talus and the patient was consequently referred to the Department of Orthopaedic Surgery at the Karolinska Hospital for further examination

On examination here the patient's general condition was found to be good He walked without a limp There was no tenderness on palpation nor was there any noticeable clinical abnormality in the right foot

X-ray

The dorsal portion of the trochlea tali contained a multiocular cystic space which posteriorly broke through the cortical bone of the posterior process of the talus





Figure 1 Figure 2

Figures 1 and 2 Radiological appearance of the lesion at the time of admission to hospital

The patient was operated upon for a neoplasm tentatively diagnosed as a giant cell tumour

Operation (September 1971)

Through an incision between the fibula and the Achilles tendon the talus was opened and the processus posterior tali dissected free and penetrated with a chisel giving easy access to the soft bone An almond sized cavity filled with grainy red tumour tissue was scraped out until solid bone was encountered on all sides The cavity was filled with a finely cut mass of heterologous bone (Kieler Knochenspan) The wound was sutured and the tissue removed from the cavity was sent off for pathological diagnosis

Postoperative course

The postoperative course was uneventful At an examination in 19 4 there were no subjective complaints and a progressing organisation of the graft was seen

Pathology

The histology was consistent with aneurysmal bone cyst The cyst presented a somewhat unusual picture with large solid portions containing osteoid tissue and numerous benign giant cells

DISCUSSION

Aneurysmal bone cyst is a well known lesion Ewing (1940) referred to it as an aneurysmal giant cell tumour and Coley (1949), Thompson (1954) and others as an atypical or subperiosteal giant cell tumour However apart from the presence of giant cells an aneurysmal bone cyst bears little resemblance to a typical giant cell tumour which has larger and multinucleated giant cells in a vascular spindle-celled stroma The fibrovascular

tissue of an aneurysmal bone cyst is honeycombed by vascular spaces, and the giant cells are small and placed around areas of haemorrhage

Whereas a giant cell tumour is invasive and aggressive, an aneurysmal bone cyst has a tendency to heal after incomplete removal or even without treatment This suggests that it may not be a true tumour, and it is possible that the lesion is a peculiar response to a circumscribed subperiosteal haemorrhage, supporting the concept of trauma as a possible aetiological factor (Barnes 1956)

Others believe that the pathomechanism underlying this lesion may be a disparity between arterial inflow and venous drainage, a point of view which is suggested by the findings of Lindbom et al (1961)

The histological appearance of our case supports the idea that "the fibro-osseous stroma of an aneurysmal bone cyst is reactive and reparative rather than a primary part of the lesion A reparative fibro osseous response associated with correction of the altered hemodynamics could also explain the variability of the degree of vascularity found at surgery " (Slowick et al 1968)

ACKNOWLEDGEMENT

The author would like to thank Associate Professor Gunnar Soderberg Department of Tumour Pathology, Karolinska Institute Stockholm for carrying out the histological investigation

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Acta orthop scand 47 3f1-3f9 1976

OSTEOARTHRITIS AT THE BASE OF THE THUMB

The Concept of Monoarticular Reconstruction

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Osteoarthritic affection of the base of the thumb involving 148 hands has been studied Isolated osteoarthritis of the trapezio metacarpal joint was found to be the largest group including a total of 111 hands Reconstruction of this particular joint by a new technique is described and long term results reported A small series of isolated osteoarthritis of the trapezio scaphoid joint is presented and reconstruction by replacing the affected articular surface of the carpal scaphoid is described Osteoarthritic involvement of more than one of the articular surfaces of the trapezium was found in a group of 31 hands. *In all of them the trapezio-metacarpal joint was predominantly affected* The rationale for monoarticular reconstruction of the trapezio-metacarpal joint regardless of the extent of involvement is discussed in detail

Key words osteoarthritis trapezio metacarpal joint trapezio scaphoid joint silicone arthroplasty

Accepted 3 iv 76

Two contradictory concepts regarding the pathogenesis of so called osteoarthritis at the base of the thumb have been described during the last decade According to the first concept in most cases degenerative changes develop at the trapezio-metacarpal joint without involving the other articular facets of the trapezium The second concept postulates that osteoarthritis always develops at all or most of the articulating surfaces of the trapezium

An interesting view has been expressed by Burton (1973) who claims that osteoarthritis at the base of the thumb develops progressively through three stages The first two stages involve the trapezio-metacarpal joint alone whereas the third most advanced stage represents a pantrapezial osteoarthritis According to his concept a panarthrosis is the final outcome of the process at the base of the thumb

Surgery, in cases which do not respond to conservative treatment, has been greatly influenced by the concept of pathogenesis adopted by the surgeon Arthrodesis of the trapezio-metacarpal joint which is probably the most commonly used surgical procedure for osteoarthritis, is based on the concept of isolated osteoarthritis of the trapezio metacarpal joint (Muller 1949 Leach & Bolton 1968 Eaton & Littler 1969, Carroll & Hill 1973) Nevertheless, excision of the trapezium has been practised by those who believe that the trapezium is the centre of a generalised osteoarthritic process (Gervis 1949 Murley 1960, Sims & Bentley 1970)

Figure 1 The drawing shows the level of resection of the metacarpal base (dotted line) and the implant introduced into the trapezio metacarpal joint Figure 1 B shows the implant as currently produced in three sizes Figure 1 C represents the radiological appearance of the trapezio metacarpal arthroplasty with the first metacarpal in abduction and adduction

A

C

B

In recent years arthroplastic procedures of the trapezio-metacarpal joint have been suggested instead of arthrodesis (Froimson 1970, Wilson 1971, personal communication) and replacement of the trapezium with a silicone implant has been advocated instead of a plain trapezial excision (Swanson 1972). Another method for arthroplasty of the trapezio-metacarpal joint has been developed and practised since 1966. This consists of a limited resection of the base of the first metacarpal and introduction of a moulded silicone implant into the gap (Figure 1).

The purpose of this paper is to report the long-term results with this type of arthroplasty and to discuss the authors' philosophy towards the pathology at the base of the thumb.

MATERIAL AND METHODS

One hundred and forty eight hands (100 patients) showing clinical and radiological signs of osteoarthritis at the base of the thumb have been examined by the authors since 1966. Seventy six hands underwent surgery; the rest were adequately relieved by conservative treatment. All 148 hands were re-evaluated during 1975. The roentgenograms of all cases were re-examined, but clinical check up could only be performed on 102 hands (72 patients). The age of the patients of the present series varied between 25 and 70 years. Seventy two were female and 28 were male. In 48 patients the affection was bilateral (96 hands) and in 52 it was unilateral. In 40 patients with unilateral affection the dominant hand was involved.

The examination of the whole series was aimed at determination of the precise location of the process. Most of the roentgenograms were taken at the same institute and consisted of two standard views of the base of the thumb: antero-posterior and lateral. In some of the roentgenograms there was no clear exposure of the joint space between the trapezium and the trapezoid; however the trapezio-scaphoid joint was well exposed in all instances.

RESULTS

Results of the survey could be summarised as follows:

1. One hundred and eleven hands showed a definite isolated osteoarthritis of the trapezio-metacarpal joint. As mentioned before, we tried to be very precise and demanding in our evaluation. Even slight and obviously insignificant variations outside the trapezio-metacarpal joint proper were considered sufficient to exclude the case from the isolated group.
2. There were six instances of isolated osteoarthritis of the trapezio-scaphoid joint.
3. Thirty-one hands showed osteoarthritic changes at multiple articular surfaces of the trapezium. While in all cases the trapezio-metacarpal joint was predominantly affected, the most common additional involvement was in the trapezio-scaphoid joint.

Isolated osteoarthritis of the trapezio-metacarpal joint

In two previous communications (Kessler & Axer 1971, Kessler 1973) a series of 60 patients affected by osteoarthritis of the trapezio-metacarpal joint has been reported. Both papers dealt mainly with technical details and described results after an arthroplastic procedure intended to reconstruct only the trapezio-metacarpal joint, without interfering with the surrounding joints. The present series of 111 hands includes the series published before, but extends the follow-up to almost 10 years. Although surgery will be discussed in some detail, the emphasis of this report is placed on the correlation between the distribution of the osteoarthritic changes and the method of treatment.

Four patients underwent arthrodesis of the trapezio-metacarpal joint. Technically arthrodesis was achieved by resection of the articular surfaces of the metacarpal base and the trapezium, apposition and fixation with K-wires (Figure 2). A firm, bony union was achieved in three instances after 10, 11

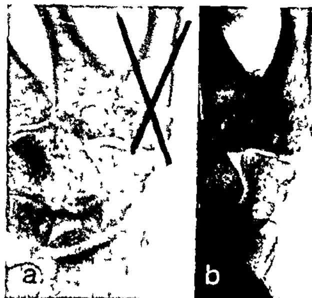


Figure 2 Arthrodesis of the trapezio-metacarpal joint Fixation is achieved by two K-wires (A) The final result is a solid bony union (B)

and 16 weeks, respectively, and one case resulted in non-union It is to be noted that follow-up in all cases was more than 8 years and in no case did the re-examination reveal any changes in the surrounding joints All four were engaged in manual occupations and were satisfied with the result (including the case with non-union) Objectively, one case demonstrated 15–20° of limitation of abduction in comparison with the other hand, the rest had unobstructed range of motion at the base of the thumb

Sixty-one hands of this series underwent silicone arthroplasty of the trapezio-metacarpal joint (Figure 1) The technique of this procedure has been described elsewhere (Kessler 197d) One point which is extensively discussed by most authors, but has not been properly covered in our previous communications, is the radial instability, or subluxation, which takes place in some of the cases with osteoarthritis of the trapezio metacarpal joint (Figure 3) It seems that the extent of osteoarthritic changes is not the only, or even the main factor, for development of radial subluxation There were many advanced cases in our series without radial instability and in some other instances, subluxation was shown in the early stages of osteoarthritis Habitual laxity of the trapezio-metacarpal joint is a well known phenomenon and radial instability can be demonstrated in people with gracile and hyperflexible joints Whether radial instability is more pronounced in patients with habitual laxity of the trapezio-metacarpal joint, or whether it develops as a result of direct involvement of the ulnar supporting apparatus in a previously stable joint, remains to be proven An interesting discovery in this respect has been made during the survey of the present series Most cases that did not show a radial instability before surgery achieved stable arthroplastic joints, without reconstruction of the ulnar supporting apparatus This fact could probably be explained by the technique that we employed A very economical resection of the base of the



Figure 3 Radial subluxation in advanced osteoarthritis of the trapezio metacarpal joint

first metacarpal in most cases would not disturb the site of attachment of the ulnar ligament. In this way the normal relation between the articulating surfaces of the trapezium and the metacarpal base bearing the silicone implant would be preserved. On the other hand some cases with preoperative instability resulted in persistent radial subluxation in spite of the uniformly improved subjective and functional condition.

Radial instability has been a constant problem in the replacement arthroplasty of the trapezium in which division of the entire supporting apparatus is a technical necessity (Burton 1973). Experience has shown that reconstruction of the ulnar ligamentous support is the only way to keep the articulating surfaces of the implant and the carpal scaphoid properly approximated. A slip of flexor carpi radialis as described by Eiken (1971) could probably also be used in arthroplastic procedures of our type in cases which show preoperative radial instability of the trapezio metacarpal joint.

Results after surgery in this series could be summarised as follows. Thirty eight hands were recorded preoperatively as stable. Thirty six of them resulted in stable arthroplastic joints without reconstruction of the ulnar supporting apparatus. In two instances the roentgenograms revealed radial subluxation. Twenty two hands showed radial instability preoperatively. Fifteen resulted in radial subluxation. In seven hands the instability disappeared after surgery in spite of the fact that no reconstruction of the ulnar supporting apparatus was performed. This phenomenon could probably be explained by excessive fibrotic encapsulation taking place during the period of immobilisation or tightening of the ulnar supporting apparatus due to the space-occupying effect of the implant.

In one case in the early series there was a complete dislocation of the metacarpal base (Kessler 1973).

All cases but one reported significant improvement after surgery. Thirty five were reported to be symptom free but in 25 hands there was some pain or discomfort after exertion. It should be noted that there was no correlation between the postoperative positioning of the joint and the patients' evaluation of results. In many cases the radial instability was not regarded as disturbing by the patients.

Isolated osteoarthritis of the trapezio scaphoid joint

As mentioned before osteoarthritic involvement of the trapezio scaphoid joint is quite uncommon. In the literature at our disposal we were able to find only one report describing a rather large series of 12 cases with isolated osteoarthritis of the trapezio-scaphoid joint (Carstam et al 1968). Among the 148 hands of our series, only six showed definite radiological signs of isolated osteoarthritis of the trapezio-scaphoid joint (Figure 4). In one patient this condition was bilateral. Four patients demonstrated unilateral affections in their dominant hands. Four cases did not respond to conservative treatment and were submitted to surgery. Here again we were faced with a simple alternative to fuse this joint or to reconstruct it. Motion at the trapezio-scaphoid joint is negligible and therefore a complicated method for reconstruction could hardly be justified. In these cases, the type of surgery should be determined by the simplicity of approach as well as by the personal preference and experience of the surgeon.

In the first two instances a simple interposition of a thin silastic sheet (501 7 0.040") was performed, after resecting the articular surface of the trapezium. The corresponding articular surface of the carpal scaphoid was left undisturbed. A short cast was applied for 2 weeks and gradually increasing activity



Figure 4 (A) Advanced isolated osteoarthritis of the trapezio scaphoid joint (B) shows an arthroplastic procedure achieved by resection of the distal articular portion of the carpal scaphoid and its replacement by a silicone implant

was encouraged thereafter No physiotherapy was necessary In less than 1 month both patients returned to their former occupations They were followed up for 6 and 7 years, respectively, and were both free of symptoms in the operated region

More recently, acting on a suggestion by Dr Eiken from Malmo (Sweden), the arthroplastic procedure of the trapezio-scaphoid joint was modified in such a way that the articular surface of the carpal scaphoid was replaced with the same silicone implant and the corresponding facet of the trapezium was left undisturbed (Figure 4 B) Although follow-up has been very brief and only two cases were operated, we feel that this procedure is superior to the first described and should be the procedure of choice in cases with isolated osteoarthritis of the trapezio-scaphoid joint The arthroplasty of the trapezio-scaphoid joint does not require any ligamentous reconstruction and a simple suture of the joint capsule seems adequate

Polyarticular osteoarthritis of the trapezium

Osteoarthritic changes involving more than one articular facet of the trapezium were diagnosed in 31 hands In all instances but one the trapezio-metacarpal joint was predominantly affected Reduced motion at the base of the thumb, various degrees of adduction contracture and advanced radiological changes were characteristic symptoms Surprisingly, in spite of the pronounced degenerative

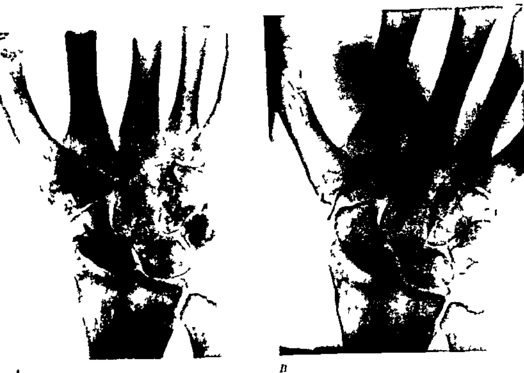


Figure 5 Pantrape ial osteoarthritis of post traumatic o igin (A) After resection of the trape ium (B) N te the u i le gap between the base of the first metacarpal and the scaphoiod

changes subjective complaints were mild to moderate

All patients were given the conven tional conservative treatment including salicilates indomethacin splinting par affin baths ultrasonic diatherms and 26 of them had a course of deep X ray therapy Seven hands did not respond to conservative treatment and were referred for surgery One of them with a very advanced polyarticular osteoarthritis of the trapezium was of post traumatic origin and involved the dominant hand of a young patient Resection of the tra pezium was carried out (Figure 5) The patient was free of symptoms when seen at about 2½ years after surgery The range of motion at the base of the thumb was normal Dynamometric measure ment showed reduced strength of pinch by about 30 per cent in comparison with the other (non dominant) hand The remaining six hands underwent silicone arthroplasty of the trapezio metacarpal joint alone In two cases release of the adduction contracture was carried out in addition to the arthroplastic procedure Considering the fact that motion of the other articulations of the trapezium is negligible and under normal circum stances the main mechanical stress is born by the trapezio-metacarpal joint, an adequate relief of symptoms was expected after the reconstruction of this particular joint After a follow up varying from 2 to 7 years results could be sum marised as follows Four cases were symptom free, two were improved but still complained of pain and discomfort after prolonged exertion In three hands the arthroplastic joints were stable and the other three showed radial instability Motion was unobstructed in all instances

DISCUSSION

The great discrepancy between the numbers of the conservatively treated and the operated patients of the isolated series, as compared with the series of polyarticular involvement of the trapezium, is the main feature brought out by the present study. More than half of the patients of the isolated series did not respond to conservative treatment and were referred for surgery; in comparison, only seven out of 31 patients of the series with polyarticular affection of the trapezium did not respond to conservative treatment. The remaining 24 showed adequate improvement after the conventional conservative treatment previously described. The greater response to conservative treatment by patients with advanced changes could probably be explained by the fact that they were all in a rather chronic condition, having previously passed the acute stage.

It is interesting to note that in many instances clinical symptoms in the relatively early osteoarthritis with isolated and incipient radiological changes were much more acute and disturbing than the symptoms reported by patients with advanced mono- or polyarticular changes of the trapezium.

Whereas arthrodesis or arthroplasty of the trapezio-metacarpal joint represents the logical management in isolated affections of this particular joint, a different approach seems to be required in a pantrapezial osteoarthritis. Resection of the trapezium, with or without inserting an implant, should provide the proper solution, by disengaging the affected articulating facets of the surrounding bones from the corresponding facets of the trapezium. This assumption would have been a very sound and reliable principle, if all joints surrounding the trapezium were of equal functional value. It is well known, however, that motion at the base of the thumb is provided mostly by the trapezio-metacarpal joint, the other joints having a minimal functional capacity. This is probably the reason for that joint being more exposed to trauma and repeated mechanical stress than any other joint or group of joints at the base of the thumb. The favourable results achieved by arthroplasty of the trapezio-metacarpal joint alone, even in cases of polyarticular involvement of the trapezium, also indicate that most symptoms in cases of osteoarthritis at the base of the thumb are predominantly related to the trapezio-metacarpal joint. Whether or not arthroplasty would delay or interrupt the further progression of osteoarthritic changes around the trapezium could not be determined by the present study.

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DISCUSSION

The great discrepancy between the numbers of the conservatively treated and the operated patients of the isolated series, as compared with the series of polyarticular involvement of the trapezium, is the main feature brought out by the present study More than half of the patients of the isolated series did not respond to conservative treatment and were referred for surgery, in comparison, only seven out of 31 patients of the series with polyarticular affection of the trapezium did not respond to conservative treatment The remaining 24 showed adequate improvement after the conventional conservative treatment previously described The greater response to conservative treatment by patients with advanced changes could probably be explained by the fact that they were all in a rather chronic condition, having previously passed the acute stage

It is interesting to note that in many instances clinical symptoms in the relatively early osteoarthritis with isolated and incipient radiological changes were much more acute and disturbing than the symptoms reported by patients with advanced mono- or polyarticular changes of the trapezium

Whereas arthrodesis or arthroplasty of the trapezio-metacarpal joint represents the logical management in isolated affections of this particular joint, a different approach seems to be required in a pantrapezial osteoarthritis Resection of the trapezium, with or without inserting an implant, should provide the proper solution, by disengaging the affected articulating facets of the surrounding bones from the corresponding facets of the trapezium This assumption would have been a very sound and reliable principle, if all joints surrounding the trapezium were of equal functional value It is well known, however, that motion at the base of the thumb is provided mostly by the trapezio metacarpal joint the other joints having a minimal functional capacity This is probably the reason for that joint being more exposed to trauma and repeated mechanical stress than any other joint or group of joints at the base of the thumb The favourable results achieved by arthroplasty of the trapezio-metacarpal joint alone, even in cases of polyarticular involvement of the trapezium, also indicate that most symptoms in cases of osteoarthritis at the base of the thumb are predominantly related to the trapezio-metacarpal joint Whether or not arthroplasty would delay or interrupt the further progression of osteoarthritic changes around the trapezium could not be determined by the present study

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DISCUSSION

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Figure 1 Osteolytic lesion of the medial third of the right clavicle There is no evidence of bone formation

ous foramina in bones often in association with blood vessels These nerves may serve as the tissue from which neurofibromas arise Most of the cases of intraosseous nerve tumour reported have been related to the proximity of nerves and nutrient foramina Fawcett & Dahlin (1967) reported seven cases of intraosseous neurogenic tumour four in the mandible and one in each of the third rib the scapula and the femur H reviewed a total of 38 cases but there were none involving the clavicle Most intraosseous neurilemmomas have occurred in the mandible the long intra osseous course of the relatively long mental nerve is probably the reason for the occurrence of neural tumours in that bone Other nerve tumours at other sites have been demonstrated close to the nutrient foramina Brooks & Lehman (1924) suggested that with the development of a neurofibroma in the periosteum there is a certain amount of reaction and bone destruction and regeneration follows This results in a certain type of subperiosteal or cortical cyst Cases of this type have been reported in the literature (Henseley 1953 Sane et al 1971) In the present case however there was no evidence of periosteal reaction Hence it seems most probable that the tumour arose from the nerve entering along with the nutrient vessels

The differential diagnosis in cyst like lesions of this type includes other benign fibrous lesions Neurilemmoma however lack the metaplastic osteoid of fibrous

Acta orthop scand 47, 370–372, 1976

INTRAOSSEOUS NEUROFIBROMA OF THE CLAVICLE

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A case of an intraosseous neurofibroma of the medial end of the clavicle, treated surgically, is reported The relevant literature i reviewed

Key words neurofibroma, clavicle

Accepted 21 iii 76

Primary nerve tumours are extremely rare Fawcett & Dahlin (1967) found seven cases in their series of 3987 primary bone tumours at the Mayo Clinic and were able to collect another 31 cases after a review of the literature No case of intraosseous neurofibroma of the clavicle either alone or in association with multiple neurofibromatosis has been reported in the literature reviewed This prompted us to report this rare case of intraosseous neurofibroma

CASE REPORT

V I a 34 year old Hindu male was admitted with complaints of progressive pain and swelling over the medial aspect of the right clavicle which had lasted for the previous 4 to 5 months There was no history of injury fever or pain or associated swelling in other parts of the body

On examination a diffuse firm oblong swelling 7 5 cm × 5 cm in size extending from the junction of the medial third of the clavicle to the suprasternal notch was seen No pressure effects were detected either proximally or distally

There was no evidence of stigmata or appearances suggestive of multiple neurofibromatosis A skiagram of the clavicle showed an osteolytic lesion of the medial third of the clavicle with no incipient new bone formation (Figure 1) A scalloped appearance of the normal medial end of the clavicle was seen Skiagrams of the chest and cervical spine and a blood examination were within normal limits

The mass was explored by an incision 10 cm long from the medial third of the clavicle to the suprasternal notch Extra periosteal resection of the clavicle 4 cm lateral to the palpable mass was done Haemostasis was maintained and the wound closed after approximating the pectoralis major and the sternomastoid The patient made an uneventful recovery At follow up after 1 year there was no recurrence of the tumour

Pathology

Gross The firm to hard irregular growth measuring 1 5 × 3 × 6 cm in size was attached at one end to a 4 cm long piece of bone The outer layer was white and streaked

Microscopic Most of the sections showed a uniform picture of well formed mature connective tissue with thin elongated nuclei with pointed ends In these regions there was no pleomorphism etc However in two of the sections towards one edge there were sufficiently large areas showing a variable degree of cellular pleomorphism and these areas also showed a ponceau positive cytoplasm There was no evidence of bony or cartilagenous tissue The overall histological appearances were in favour of a neurogenic tumour of very low malignancy or a fibroblastic tumour

DISCUSSION

Miller & Kasharn (1963) and Sherman (1963) demonstrated both myelinated and non-myelinated nerves entering vari

Acta orthop scand 47, 373-374, 1976

SYNOVIAL CHONDROMATOSIS OF THE INFERIOR RADIO-ULNAR JOINT

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Synovial chondromatosis is an extremely rare affection of the inferior radio ulnar joint The case in this study presented with mild episodes of swelling and pain in the wrist and discomfort during forearm rotation

Key words synovial chondromatosis, inferior radio ulnar joint

Accepted 11 iv 76

CASE REPORT

A 29 year-old male loader presented with a history of recurrent episodes of swelling and pain in the right wrist over the previous 6 months He had sustained a trivial injury to his wrist at the onset but was not absent from work He described his symptoms as a continuous discomfort with occasional stabs of pain in the wrist especially when it was turned, and stiffness and weakness of the grip Clinical examination revealed a slightly hard swelling over the front of the wrist this was generally pain free but rotation produced an acute pain especially on supination No evidence of median nerve compression was found Radiographs showed the existence of multiple small free bodies lying in the recess between the radius and ulna more noticeable on the palmar than the dorsal side *Figure 1*

At surgery through a transverse incision at the palmar of the wrist the capsule of the inferior radio ulnar joint was opened and eight yellow grey small cartilagenous nodules removed Histological sections taken from the excised specimens showed extensive cartilagenous areas with evidence of secondary ossification and with cartilagenous foci in the synovial membrane The pathological diagnosis was synovial chondromatosis

Postoperatively the patient developed a temporary limitation of the full extension of the last three fingers, due to adhesions of the flexor tendons This recovered fully and the patient resumed his usual duties

DISCUSSION

Articular synovial chondromatosis most often affects the knee, hip or elbow (Eisenberg & Johnston 1972, Freund 1937, Jeffreys 1967, McIvor & King 1962, Murphy et al 1962, Mussey & Henderson 1949), and rarely the ankle (Murphy et al 1962, Mussey & Henderson 1949), shoulder (Freund 1937, Paul & Leach 1970), jaw joint (Silver et al 1971), wrist (Bibergeil 1913, Murphy et al 1962, Riedel 1917), and interphalangeal joints of the hand (Kettlekamp & Dolan 1966, Lewis et al 1974) The inferior radio-ulnar joint appears to be a very uncommon site for this condition

The inferior radio-ulnar joint is an extremely unusual localization of synovial chondromatosis A review of the existing literature showed only three cases of involvement of the wrist (Bibergeil 1913, Murphy et al 1962, Riedel 1917), two of them reported in the years 1903 and 1913

dysplasia, the giant cells of fibroma of bone and the whorled dense fibrous tissue of the desmoplastic fibroma In the present case, there was initially difficulty in arriving at a diagnosis but a detailed examination of the blocks of the tissue coupled with systematic exclusion of other lesions pointed to the diagnosis of neurofibroma

ACKNOWLEDGEMENTS

I am grateful to Dr N S Pathania Principal and Dean Govt Medical College and S M G S Hospital Jammu for permission to publish this case and I am indebted to Dr Dutta of the Post Graduate Institute Chandigarh and Dr S Sriramachari of the Indian Registry of Pathology, Safdarganj Hospital New Delhi for histopathological examination

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Acta orthop scand 47 375–380 1976

SUPRACONDYLAR FRACTURES OF THE HUMERUS IN CHILDREN

A Follow-up with Particular Reference to Late Results after Severely Displaced Fractures

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A follow up of 73 cases out of a 10 year material of 90 children with supracondylar fractures of the humerus is described Forty three children had fractures with gross displacement whereas 30 children had undisplaced or slightly displaced fractures This last group all achieved excellent results after simple conservative treatment Twenty three cases among the group with severe displacement were treated with vertical extension 17 cases with one or more attempts at manipulative reduction and plaster fixation and three with operation using Kirschner wires The functional results were approximately the same in the first two groups and were satisfactory in 85–100 per cent The results with varus derformity were better in the group treated by extension (82 per cent as opposed to 50 per cent in the group treated by manual reposition) We conclude that extension in a vertical direction is the most suitable method of treatment of these often severely displaced fractures

Key words humerus supracondylar fracture overhead traction

Accepted 15 iv 76

The management of undislocated or slightly dislocated supracondylar fractures of the humerus seldom gives rise to difficulty whereas severely dislocated fractures give great problems and often leave the surgeon undecided as to the best treatment

Since Jensenius (1948) followed up the results in 75 children with supracondylar fractures s c f) treated non-operatively and concluded that a better technique of reposition was desirable various other methods have become commonplace This department has treated a relatively large number of children with s c f over a 10 year period Since a method of vertical extension instead of repeated reposition and plaster fixation has been used with increasing frequency follow up of these cases has been found to be of value

MATERIAL AND METHODS

During the years 1962 1971 90 children with s c f were admitted to this hospital Age and sex are shown in Figure 1 and are similar to the

[illegible] undislocated fractures grade 2 fractures with slight lateral displacement grade 3 fractures with rotational displacement and



Figure 1 Radiographs of the inferior radio ulnar joint to show the existence of multiple small free bodies lying in the recess between the radius and ulna (a) In the lateral view (b) these nodules are more noticeable on the palmar side

As the inferior radio ulnar joint does not communicate with the carpal joint the present case must be considered as a different localization

Episodes of mild swelling of the joint pain and stiffness are common symptoms of articular synovial chondromatosis (Murphy et al 1962, Paul & Leach 1970) These symptoms are often very mild so diagnosis tends to be delayed until suggested by X rays (Murphy et al 1962)

Median nerve compression is theoretically possible, and it has been described as a postoperative complication (Murphy et al 1962), it did not, however occur in this case

ACKNOWLEDGMENTS

The author wishes to thank Mr W Kellock FRCS for permission to present this case and Dr Read for the histologic examination

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Table 1 Varus deformity measured radiologically at the proximal humero ulnar angle in 41 children with grade 3 and 4 supracondylar fractures

Difference in proximal humero ulnar angle on the two sides	Fractures treated by vertical extension	Fractures treated by reduction and plaster fixation	Internal fixation
0–5°	14	6	3
6–10°	4	2	
11–15°	1	6	
over 15°	3	2	
Total	22	16	3

as exact a correction of angular deformity and rotation as possible particularly with reference to the profile views from which it could be judged whether or not the anterior cortical edges were continuous with each other. These objectives seem to be achieved as no patients treated by traction were later treated by other methods because of unsatisfactory reduction. In 19 cases traction was applied on the day of injury whereas seven cases began with this treatment after a delay of 3–7 days among them five children transferred from other departments because of unsatisfactory *reduction*. *Traction* was maintained for 2–3 weeks depending on the radiological and clinical signs of union and was followed by a dorsal plaster slab for another 2 weeks after which mobilisation with active movements was begun.

Twenty four children were treated by reduction and a plaster slab for 5 weeks among these 24 was the only child in this series with an open fracture. Three of these children were later treated by internal fixation after the failure of conservative treatment. Two cases were operated upon because of suspected arterial compression but in both cases only a fasciotomy was performed. Both were then treated by extension. In the group treated by plaster fixation neurolyses of the ulnar nerve was carried out in one case 3 weeks after the accident because of diminished nerve function.

Seven of the children treated by extension had signs of superficial infection because of this three of these cases continued treatment with plaster fixation (on the 12th, 14th and 17th day). There were no cases of deeper infection or osteitis.

Signs of ulnar irritation from the Kirschner wire were present in four cases (two with paraesthesia and two with hyperaesthesia). One of *these cases* was subsequently treated by plaster splint. There were no cases of Volkmann's contracture.

FOLLOW UP

Seventy patients were assessed clinically and radiologically after an interval of between 1 to 10 years (an average of 7 years 3 months). In three cases we received only the answer to a questionnaire, whereas 17 patients did not reply either to the outpatient appointment or to the questionnaire. Among the 40 children in

Table 2 Flexion in the elbow in 43 children after supracondylar fractures

Movement	Fractures treated by vertical extension	Fractures treated by reduction and plaster fixation	Internal fixation
Normal flexion	16	14	1
5–10° lack of flexion	4	2	2
Over 10° lack of flexion	3	1	0
Total	23	17	3

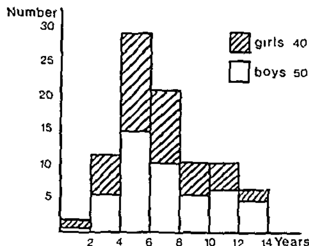


Figure 1 Age and sex distribution in 90 children admitted with supracondylar fractures

grade 4 fractures with gross displacement without contact between the fragments

Forty children had undisplaced or slightly laterally displaced fractures (grades 1 and 2). These were treated by plaster splints in some cases after reduction. The remaining 50 children had various degrees of rotational deformity, most of them (45/50) with additional complete lateral displacement without bony contact (grades 3 and 4). All were of the extension fracture type.

Twenty-six children were treated by so called overhead traction with the aid of a Kirschner wire through the olecranon. Reposition was performed under full anaesthesia in all cases. If a satisfactory position could not be maintained by plaster fixation with the elbow in 70 flexion, traction by a Kirschner wire through the olecranon was performed immediately. The skin was disinfected with 5 per cent iodine and the wire introduced through a small incision on the ulnar side. The arm was positioned over the patient's neck and head so that the hand pointed towards the top corner on the opposite side of the bed. Soft tissue traction on the upper arm was used as counter traction (Figure 2). After X-ray control on the following day any necessary alterations in the traction could be made and a lateral displacement could be corrected by careful pressure without discomfort to the patient. The aim of the traction was to obtain

Figure 2 Position of an arm with s c f treated with overhead traction. Traction is by a Kirschner wire through the olecranon. Counter traction applied to the upper arm. The arm is pointing towards the top corner on the opposite side of the bed with the aid of soft tissue traction

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Table II Flexion in the elbow in 43 children after supracondylar fractures

Movement	Fractures treated by vertical extension	Fractures treated by reduction and plaster fixation	Internal fixation
Normal flexion	16	14	1
5–10° lack of flexion	4	2	2
Over 10° lack of flexion	3	1	0
Total	23	17	3

Table 3 Extension in the elbow in 43 children after supracondylar fractures

Movement	Fractures treated by vertical extension	Fractures treated by reduction and plaster extension	Internal fixation
Normal extension	19	15	1
5–10° lack of extension	3	2	0
Over 10° lack of extension	1	0	2
Total	23	17	3

groups 1 and 2, 30 were examined and the results in all cases were normal anatomically and functionally.

In the group of 50 children with fractures, primarily in groups 3 and 4, 43 were reviewed and of these 41 were X-rayed.

Table 1 shows the results with reference to varus deformity, which was more than 10° in four children treated by extension, and in eight children treated by reposition and plaster Results in this respect could be described as excellent or good in 82 per cent (18/22) and 50 per cent (8/16), respectively

Tables 2 and 3 show the final flexion-extension movements Here the results are approximately the same, with 87 per cent (20/23) and 94 per cent (16/17), respectively, excellent or good results for flexion, and 96 per cent (22/23) and 100 per cent (17/17) for extension

Pronation-supination was normal in all cases, with the exception of two of the three children treated by osteosynthesis Myositis ossificans developed in only one child, and it was treated by osteosynthesis Six children complained in the questionnaire of reduced arm strength, and five of these had been treated by traction Five children, all belonging to the group treated by plaster fixation, complained of tenderness localised to the ulnar nerve, and two of these had par aesthesia in the ulnar distribution of the hand

DISCUSSION

As in other series (Holmberg 1945, Hammond 1952, Høyer 1952, Smith 1960) our follow-up of 73 children with s c f shows that the functional result is satisfactory in almost all cases, including cases with gross displacement, of which there were 50 in this series On the other hand, both in our series and in other published articles there are a certain number of cosmetically poor results, almost all of them due to alteration in the bearing angle of the arm with resulting varus deformity (gunstock deformity) The incidence of this is given as between 9 and 57 per cent (Høyer 1952) In our series this deformity was seen in 12 of the 43 children with serious fractures (28 per cent)

Smith (1960) has argued convincingly that this varus deformity can develop only as the result of the distal fragment tipping sideways compared to the humeral shaft, neither rotation nor lateral deformity, but the combination of an oblique fracture line and muscle pull can lead to secondary tilting As a result of this, treatment with continuous traction must be particularly suitable in preventing varus deformity, this is supported by other authors (Andersen & Jacobsen 1967, Bakalim & Wirppula 1972) and seems to be confirmed by our results

Many modifications of extension treatment have been described Supporters of the so called side traction (Maylahn &

Lahey 1958, Bates & Taylor 1971) consider this an easy method for the patient, in that it gives sufficient elevation and at the same time a possibility for controlling the forearm, and therefore the rotation of the distal humeral fragments (Windfeld 1948, Madsen 1955, El Sharkawi & Fattah 1965). Madsen (1955), for instance, has emphasised the significance of reduction with lateral traction and simultaneous lateral rotation of the arm, followed by plaster fixation in the "hurrah position". The majority of authors, however, are supporters of traction in a vertical direction (Baumann 1931, Hammond 1952, Smith 1960, Edmann & Löhr 1963, Shubert & Forberger 1971, D'Ambrosia 1972). D'Ambrosia (1972) has found from cadaveric experiments that flexion of the forearm in pronation contributes to the prevention of varus deformity, and that rotating the hand over the head corrects the rotational deformity. Another advantage of vertical extension is the simultaneous treatment of the frequently massive oedema, and there is easy access for clinical observation, X-ray control and, if necessary, adjustment of the extension. The disadvantage is the length of time in bed and the period in the hospital, and the risk of infection and damage to the ulnar nerve, which must not be forgotten.

According to Smith (1960) the infection rate can be reduced by the use of a Kirschner wire with a screw thread, which does not move in the bony canal in the ulna. These difficulties are presumably the reason why conservative treatment is still the most popular method.

The simplest and possibly the best method is Charnley's (1968) collar and cuff, where the arm is fixed with fully flexed elbow; as long as this position is maintained, the reduction is secure. The complications are partly the increase of oedema because of the hyperflexed elbow, and partly, that the bandage works loose, resulting in a new displacement at the fracture site. The danger of redislocation is greater, if the elbow is simply immobilised at a right angle in a plaster cast, even though Böhler's (1938) technique is used with fixation in a position of maximal pronation.

Plaster fixation in greater flexion increases the danger of arterial dysfunction with the following risk of ischaemia of the forearm and hand. We consider that this risk also contraindicates the use of circular plasters in these fractures.

Lastly, open reduction with or without internal fixation is fairly frequent and Holmberg (1945) found 61 per cent good results after fixation with Rissler pins followed by plaster. Others emphasised the significance of so solid an internal fixation as to make plaster unnecessary (Haddad et al. 1970).

Carcasone et al. (1972) found up to 97.5 per cent satisfactory results in a series of 40 children treated by operation. They recommend an operative technique using an anterior approach through the already damaged brachialis muscle, thereby protecting the triceps brachii. In our series operation was only used in three cases, which does not permit any conclusion as to its viability in the treatment of these fractures.

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Table 3 Extension in the elbow in 43 children after supracondylar fractures

Movement	Fractures treated by vertical extension	Fractures treated by reduction and plaster extension	Internal fixation
Normal extension	19	15	1
5–10° lack of extension	3	2	0
Over 10° lack of extension	1	0	2
Total	23	17	3

groups 1 and 2, 30 were examined and the results in all cases were normal anatomically and functionally.

In the group of 50 children with fractures, primarily in groups 3 and 4, 43 were reviewed and of these 41 were X-rayed

Table 1 shows the results with reference to varus deformity, which was more than 10° in four children treated by extension, and in eight children treated by reposition and plaster Results in this respect could be described as excellent or good in 82 per cent (18/22) and 50 per cent (8/16), respectively

Tables 2 and 3 show the final flexion-extension movements Here the results are approximately the same, with 87 per cent (20/23) and 94 per cent (16/17), respectively, excellent or good results for flexion, and 96 per cent (22/23) and 100 per cent (17/17) for extension

Pronation-supination was normal in all cases, with the exception of two of the three children treated by osteosynthesis Myositis ossificans developed in only one child, and it was treated by osteosynthesis Six children complained in the questionnaire of reduced arm strength, and five of these had been treated by traction Five children, all belonging to the group treated by plaster fixation, complained of tenderness localised to the ulnar nerve, and two of these had paraesthesia in the ulnar distribution of the hand.

DISCUSSION

As in other series (Holmberg 1945, Hammond 1952, Høyer 1952, Smith 1960) our follow-up of 73 children with s c f shows that the functional result is satisfactory in almost all cases, including cases with gross displacement, of which there were 50 in this series On the other hand, both in our series and in other published articles there are a certain number of cosmetically poor results, almost all of them due to alteration in the bearing angle of the arm with resulting varus deformity (gunstock deformity) The incidence of this is given as between 9 and 57 per cent (Høyer 1952) In our series this deformity was seen in 12 of the 43 children with serious fractures (28 per cent)

Smith (1960) has argued convincingly that this varus deformity can develop only as the result of the distal fragment tipping sideways compared to the humeral shaft neither rotation nor lateral deformity, but the combination of an oblique fracture line and muscle pull can lead to secondary tilting As a result of this, treatment with continuous traction must be particularly suitable in preventing varus deformity, this is supported by other authors (Andersen & Jacobsen 1967, Bakalim & Wirppula 1972) and seems to be confirmed by our results

Many modifications of extension treatment have been described Supporters of the so-called side traction (Maylahn &

Acta orthop scand 47, 381-387, 1976

A STUDY OF PAINFUL SHOULDER IN WELDERS

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By means of clinical examination, soft tissue radiography and quantitative electromyography, the effect of heavy industrial work was evaluated on welders at a shipyard The study revealed that the older workers with shoulder pain have a chronic tendinitis of the rotator cuff The supraspinatus muscle was shown to be consistently fatigued during overhead welding It is believed that this is an important factor in the aetiology of the shoulder pain commonly occurring in older welders

Key words shoulder pain, supraspinatus tendinitis electromyography, soft tissue radiography, occupational disease, welding

Accepted 10 x 76

Next to low back pain shoulder pain is the most frequent complaint among orthopaedic patients Despite the frequency of shoulder lesions and the consequent pain and disability, much confusion still exists as to aetiology, terminology and treatment This confusion stems from our incomplete understanding of the basic pathophysiology of shoulder pain Clinically, supraspinatus tendinitis and adhesive capsulitis account for the vast majority of cases of shoulder pain (Bateman 1972, Lundberg 1969, Moseley 1969 Pasila 1965) These two conditions can be easily differentiated during clinical examination In supraspinatus tendinitis the range of motion is normal whereas in adhesive capsulitis shoulder motion is restricted

Manual labour as a source of shoulder pain has been of great concern for many decades Many writers have postulated an area of degenerative changes and necrosis in a critical zone of the rotator cuff, resulting from the ischaemia of chronic postural strain, or repeated minor trauma, as important aetiological factors (Codman 1934, Wilson 1943) However, previous investigations have failed to show how heavy manual labour affects the development of progressive degenerative changes and hence subsequent shoulder pain (Olsson 1953, Pasila 1965) Most studies have been made on selected clinical materials and on autopsy specimens

During a recent investigation, heavy static shoulder work, viz, welding at a shipyard, was studied by means of quantitative electromyography (Kadefors et al 1976) It was concluded that localized muscle fatigue was common, among inexperienced welders, in the deltoid, trapezius (upper portion), and supraspinatus muscles during prolonged overhead work Experienced workers showed signs of fatigue in the supraspinatus muscle only On completing this in-

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Figure 1 The working posture investigated Overhead welding involves shoulder flexion and abduction

This variable (given in decibels) is studied as a continuous function of time

Myoelectric signals were recorded during overhead welding illustrated in Figure 1 Four welding electrodes were melted at 40 cm height above the shoulder at a normal working pace The spectral content of the myoelectric signals was characterized as described above and then normalized to the initial value taken at the onset of melting the first welding electrode Readings were taken at the beginning of each of the subsequent weldings Statistical treatment was carried out as described by Kadefors et al 1976 The relation between high frequency spectral content and the welding electrode number was studied using the linear regression method

The subjects were called in for a clinical electromyographic routine investigation of the three muscles involved in the study Conventional concentric needle electrodes were utilized

RESULTS

The most consistent finding in the clinical examination was a reduced muscle power and pain on resisted movements in the painful shoulder At inspection all subjects had normal shoulders Mild local tenderness of the rotator cuff was always present There was full range of active motion in all cases Measurement of the isometric muscle power revealed reduced power in the painful shoulder in abduction outward rotation and flexion The results are depicted in Figure 2 In extension inward rotation and abduction the gross power was found to be the same in both shoulders Pain in resisted movements was noted by most subjects in outward rotation and flexion (8 out of 10 cases) and in abduction by less than half of them (4 out of 10 cases)

The radiographic appearance was normal in three shoulders only The main abnormality observed, blurring of the fatty layer, was found in six cases One such shoulder is illustrated in Figure 3

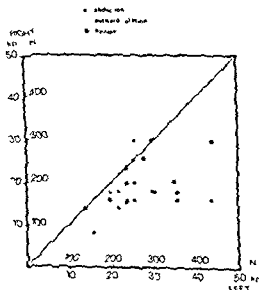


Figure 2 Maximal force in resisted movements comparing left and right side

vestigation we became aware of the fact that complaints of shoulder pain were very common among older welders We postulated that shoulder pain may be aggravated or perhaps even caused by the occupation of welding Welding is a largely static type of work with typical postures that are characterized by specific patterns of motion of the shoulder joint complex

This investigation was undertaken,

(a) to elucidate more clearly the clinical and roentgenographic features of shoulder pain in older welders,
(b) to evaluate the impact of static loading on their shoulder muscles (and the subsequent localized muscle fatigue) by quantitative electromyography

MATERIALS AND METHODS

Subjects

The study was performed on ten welders aged between 50 and 65 years The subjects were picked from various workshops at the Arendal shipyard of Gotaverken Ltd in Gothenburg All of them experienced pain around their loaded shoulder while welding None of them had a history of any major trauma to the shoulder joint or had any other specific joint disease For the greater part of their productive lifetime they had been working as shipyard welders

With respect to pain the following criteria had to be fulfilled

1 Located in the deltoid area
2 Chronic in its duration
3 Aggravated by shoulder motion especially loading of the arm above 60° of abduction and/or flexion

Great care was taken to exclude subjects with possible differential diagnoses accounting for the shoulder pain Out of 15 subjects initially selected, five were excluded because subsequent evaluation revealed a radicular syndrome from the cervical spine (4 cases) or a lateral humeral epicondylitis (1 case)

Clinical examination

The clinical examination consisted of inspection palpation and assessment of range of motion and gross power Both shoulders were studied and compared The total range of motion active and passive was measured in the sitting position using a goniometer Static gross power was evaluated in the supine position according to Clarke et al (1950) utilizing a special dynamometer (Zadig 1963) Pain in resisted movements was recorded

Roentgenographic technique

The soft tissue radiographic technique described by Deichgraber & Olsson (1975) was used This technique allows demonstration of local inflammation in tendinitis even in the absence of calcific deposits It is assumed that inflammatory reactions cause the surrounding tissues to become oedematous thus reducing the differences in attenuation capacity between them For the subacromial region this means that the subdeltoid fatty layer should become blurred or displaced on the film in cases of tendinitis Two anteroposterior projections were taken of the shoulder one with the arm rotated inwards the other with outward rotation to demonstrate the tissues adjacent to the greater and lesser tubercles of the humerus respectively

Electromyographic investigations

Recordings of the myoelectric activity of shoulder muscles were performed during overhead welding The methods employed in acquisition and analysis were identical to those reported by Kadefors et al (1976) In the present study particular attention was paid to three muscles (deltoid trapezius supraspinatus) in which significant effects were found in the basic investigation Surface electrodes (Medelec Ltd) were applied to pick up EMG from m trapezius and m deltoideus (anterior portion) Myoelectric signals from the supraspinatus were obtained using a monopolar Karma wire electrode inserted by means of a cannula A surface electrode applied over the spinal processus at level Th 5 served as a reference for the supraspinatus lead

The dynamic power spectrum analysis method was described by Kadefors et al (1968) The particular instrument used developed by Örtengren (1975) consists of an octave filter bank with full wave rectifiers for each filter output In the present study only the 500 Hz filter covering the range of approximately 350–700 Hz was employed The rectified signal is logarithmically converted and compared with the level of the rectified and logarithmically converted total EMG The differences between these two signal levels expresses the portion of high frequency signal content in the total signal

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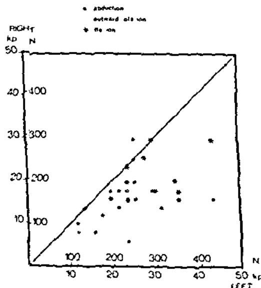


Figure 2 Maximal force in resisted movements, comparing left and right side



Figure 3. Shoulder joint in which the fatty layer is indicated by the arrow at the top. In the tubercular area (indicated by the lower arrow) local blurring of the fatty layer is seen.

In a majority of cases the fatty layer was invisible over a distance of 0.5 to 1 cm close to the most protruding part of the greater tubercle. The degree of blurring did not seem to indicate the severity of the condition from the clinical point of view. Two of the same six subjects had calcifications in addition to the blurring. Lateral displacement of the fatty layer was encountered in one case only.

It is seen in Table 1, summarizing the results of the myoelectric signal analysis, that the high frequency content for the supraspinatus muscle in particular tends to be higher in welding electrode no. 1 than in subsequent welding electrodes. This is further underlined in the regression analysis (see Figure 4). Computation of confidence intervals of the slope yields that the decline of the supraspinatus high frequency component is significant at the 5 per cent level. Neither of the remaining two muscles shows significant changes.

Analysis of the EMG from the three muscles concerned according to conventional neurophysiological criteria revealed no pathological findings.

DISCUSSION

The present study has revealed that the older welders with shoulder pain have a

Table 1. The portion (in dB) of the total myoelectric activity within the [illegible] Hz band at the onset of melting the different welding electrodes. Mean values and standard errors (italics). Individually normalized data.

Muscle	Welding electrode no. 1	2	3	4	Linear regression analysis: Slope dB/weld	95 per cent confidence interval
Deltoideus	−0.[illegible]2 *[illegible]*	0.44 *0.59*	0.[illegible] *0.61*	[illegible] *[illegible]*	0.16	±0.59
Trapezius	0.5[illegible] *0.31*	0.69 *[illegible]*	0.08 *[illegible]*	[illegible] *[illegible]*	0.23	±0.35
Supraspinatus	1.05 *0.4[illegible]*	0.05 *0.34*	0.[illegible] *[illegible]*	0.25 *[illegible]*	0.46	±0.38

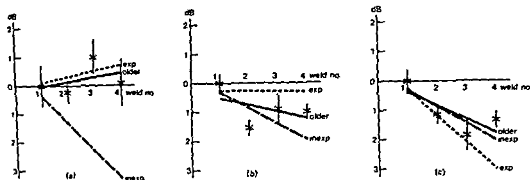


Figure 3 The development of the 500 Hz myoelectric signal component as a function of the welding electrode number Mean values and standard errors are given for each weld according to Table 1 Regression lines are shown for the present material of older welders as well as for experienced (exp) and inexperienced (inexp) welders (Kadefors et al 1976) (a) deltoideus, (b) trapezius (c) supraspinatus muscle Overhead welding

chronic tendinitis of the rotator cuff The tenderness and the amount of pain on resisted movements suggest that the lesion is located in the supraspinatus area of the cuff, an area that has been shown to be most often affected (Codman 1934, DePalma 1950) According to Pasila (1965) the symptoms were termed mild or moderate since the subjects had almost normal active range of motion and since night pain was occasional and working disability rare Nonetheless the pain was of considerable duration and constantly present at work and in leisure time as well It is important to note that older workers often have to give up welding before the age of 60 because of chronic shoulder pain

Soft tissue radiography demonstrated inflammatory abnormalities in the majority of cases The results agree with Deichgraber & Olsson (1975) who also found this type of local inflammation in patients with tendinitis

The supraspinatus tendinitis present in these welders is certainly due to degenerative changes It is well known that such changes appear in the tendons in the third and fourth decades (Ingelmark 1948) Varying degrees of rotator cuff ruptures are most common in the supraspinatus area close to the tendon insertion into bone (DePalma 1950, Olsson 1953) In the majority of cases they arise without appreciable trauma Many authors have attributed the degeneration of the cuff to repeated minor trauma but there is disagreement as to how this takes place Codman (1934) thought that the small accidents of everyday life were responsible and Meyer (1937) suggested that the tendons were subjected to trauma between the humeral head and the acromion during normal movements of the shoulder

Progressive impairment of the blood supply to the cuff has been discussed as a factor contributing to degeneration with increasing age Several investigations have shown areas of relative avascularity in the supraspinatus tendon adjacent to its point of insertion (Lindblom 1939, Moseley & Goldie 1963) Recently Rathburn & Macnab (1970) studied the vascular supply by microangiography and were thus able to compare the findings with the histological appearance of the same part of the tendon The most remarkable feature of this investigation was that the zone of avascularity was constantly seen in the supraspinatus tendon whereas the other tendons comprising the rotator cuff showed good filling of the vascular bed They attributed this



Figure 3 Shoulder joint in which the fatty layer is indicated by the arrow at the top In the tubercular area (indicated by the lower arrow) local blurring of the fatty layer is seen

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Deltoideus	− 0 22 *0 73*	− 0 44 *0 39*	0 78 *0 61*	− 0 11 *0 82*	+ 0 16	± 0 59
Trapezius	0 86 *0 31*	− 0 09 *0 27*	− 0 03 *0 52*	− 0 14 *0 26*	− 0 23	± 0 35
Supraspinatus	1 05 *0 42*	0 05 *0 34*	− 0 75 *0 55*	− 0 25 *0 29*	− 0 46	± 0 39

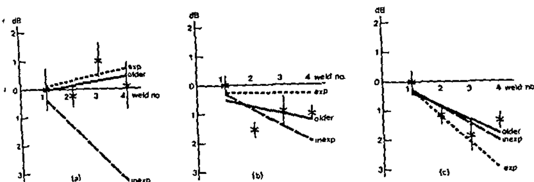


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Deltoideus	−0 22 *0 73*	−0 14 *0 39*	0 78 *0 61*	− 0 11 *0 82*	+ 0 16	± 0 59
Trapezius	0 86 *0 31*	−0 69 *0 27*	−0 03 *0 52*	− 0 14 *0 26*	0 23	± 0 35
Supraspinatus	1 05 *0 42*	−0 05 *0 3[illegible]*	0 75 *0 55*	0 25 *0 29*	0 46	± 0 39

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to the anatomical disposition of the vessels running mostly longitudinally along the flat tendon This disposition of the vessels renders them susceptible to traction and direct pressure

Analysis of electromyographic signals recorded in actual welding work revealed significant changes in the supraspinatus muscle as overhead welding proceeded No statistically significant modifications were evident in the trapezius or in the deltoid muscle Overhead welding was studied in a previous investigation (Kadefors et al 1976) on fairly young experienced and inexperienced welders and it was noted that the characteristics of the older welders investigated here were similar to those of the experienced group in the basic investigation

The spectral changes evident here are attributed to an increase in the average duration of the potentials of motor units active in the muscle (Kadefors et al 1968, Lindstrom et al 1970), caused by a decrease in action potential propagation velocity of the muscle fibres concerned (Broman 1973, Lindstrom et al 1970) Such spectral changes occur as an adjunct to heavy isometric contractions (Kadefors et al 1968, Kaiser & Petersen 1963) and represent interference with the blood supply of the muscle with resultant "localized muscle fatigue" (Chaffin 1973)

The significant spectral changes in myoelectric signals obtained from the supraspinatus muscle during prolonged overhead work imply that this muscle is under sustained heavy strain in this working situation It is interesting to note that acquisition of skill in welding does not entail immunity as far as loading the supraspinatus muscle in overhead work is concerned, in contrast to the situation with the trapezius and deltoid muscles The supraspinatus muscle is constantly fatigued in overhead welding

In conclusion, we agree with the general view that the degenerative changes present in the supraspinatus tendon of elderly people are primarily due to a diminished vascularity of the tendon with advancing age Overhead welding presents an undesirable working situation involving heavy static loading on the supraspinatus muscle The constant traction in the tendon probably accelerates the degeneration by circulatory impairment We believe that this is a major aetiological factor for the subsequent shoulder pain occurring in older welders

ACKNOWLEDGEMENTS

We are indebted to Professor Ingemar Petersén for advice throughout this study, which he initiated and would like to thank Dr F Deichgraber for performing the radiographic examination

Financial aid was donated by Gotaverken Ltd and The Swedish Work Environment Fund.

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Acta orthop scand 47, 388-390, 1976

INTRATHECAL PREDNISOLONE THERAPY IN POSTOPERATIVE ARACHNOIDITIS FOLLOWING OPERATION OF HERNIATED DISC

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Fourteen patients with severe, chronic sciatica operated on repeatedly but without lasting success were treated by two intrathecal injections of methyl prednisolone (40 mg and 80 mg) at an interval of a few days Significant improvement was obtained with regard to pain in many cases, but as there was no control series it is difficult to assess the results

Key words intrathecal methyl prednisolone, postoperative arachnoiditis

Accepted 10 ix 76

In lumbago and sciatica prednisolone preparations have mostly been administered by epidural injection, and a number of investigators have obtained good or very good results (Barry & Keendall 1962, Beliveau 1971, Brun & Langdon 1974, Harley 1967) Few accounts have been published on intrathecal injection (Seghal et al 1963), but, on the whole, encouraging results have been reported Orthopaedic clinics see many patients with severe sciatica of long standing, which prevents the patient from working, in whom all types of treatment have been tried without success, and on whom one or many exploratory operations or removal of herniated discs have been performed In such severe chronic states myelography often discloses diffuse arachnoiditis with imperfect filling of the root sheaths and constriction of the whole dural canal In this department we have treated difficult cases such as these by giving two intrathecal injections of methyl prednisolone at an interval of 3 7 days

PATIENTS AND METHODS

The age of the patients ranged between 27 and 75 years (mean age 42 years) Twelve were men and two women all had had severe sciatica for at least 6 months and all had been operated on one to three times (Table 1) The first injection 40 mg of methyl prednisolone was given in connection with a lumbar puncture (Depo medrone®) After an interval of 3 to 7 days a second injection this time of 80 mg was given

The following features were recorded before and after treatment

1) Pain on walking
2) Pain on standing still
3) Pain on sitting
4) Pain at rest

To obtain a measure of these different degrees of pain the patient was asked to indicate his sensations on a line the left end point of which corresponded to no pain and the right end point to extreme pain (Figure 1)

In recording pain after the conclusion of treatment the patient was able to refer to the previ



Figure 1 The line used by patients to indicate different degrees of pain

ous graph and could therefore grade any improvement or deterioration with respect to his previous assessment

Table 1 Case reports and percentage improvement after treatment

No	Age	Sex	No of op	Total improvement %
1	4[illegible]	M	1	46
2	36	M	1	30
3	40	M	1	0
4	27	F	2	0
5	31	M	3	15
6	52	M	1	69
7	53	M	1	55
8	75	M	1	18
9	32	M	1	11
10	43	M	2	10
11	52	F	1	11
12	50	M	2	10
13	53	M	2	53
14	47	M	1	0

Statistical evaluation

Significant improvement ($P < 0.01$) after treatment was recorded for the series taken as a whole with regard to pain on standing Significant improvement was also noted for pain on walking pain on sitting and pain at rest ($P = 0.05$) Figure 2)

RESULTS

Three characteristic cases serve to illustrate the results

Case 1

The patient a 53 year-old male with herniation of disc L4 L5 had been operated on twice in 1960 and 1972 The second operation produced no improvement He complained of constant pain radiating to the left leg and pain at rest Lasegue's test was positive on the left side giving pain at 30° extension Depomedrone was given intrathecally on 22/11 and 29/11 1973 and the patient was discharged in an improved condition and with much less pain On re examination 3 months later the patient had again deteriorated and complained of pain at rest but the symptoms were less severe than before injection therapy Lasègue's test was positive at 75° extension

Case 2

This patient a 52 year old male was operated on in 1967 for herniated disc (L5–S1 *left side*) with improvement From 1969 the patient suffered increasingly from lumbago and sciatica the pain radiating to the left leg Lasegue's test gave pain at 40° extension and the patient was discharged in a much improved condition There was practically no pain at rest, and Lasegue's test was negative On re examination after 3 months the patient was still free from pain and had been able to resume work

Case 3

The patient a 31 year old male had an exploratory operation in 1968 owing to herniated disc (L5–S1) Fusion of L5–S1 was carried out in 1968 In 1973 laminectomy L5-S1 with division of adhesions was performed None of these operations produced any improvement and the patient suffered from constant pain at rest and pain on weightbearing Lasègue's test was positive on both sides at approx 30° extension On two occasions in November 1973 Depomedrone was injected without improvement

After the first injection one of the patients experienced pain in the back and both legs similar to his usual sciatica but rather worse This new pain subsided after a few days rest In the other patients no complications were noted

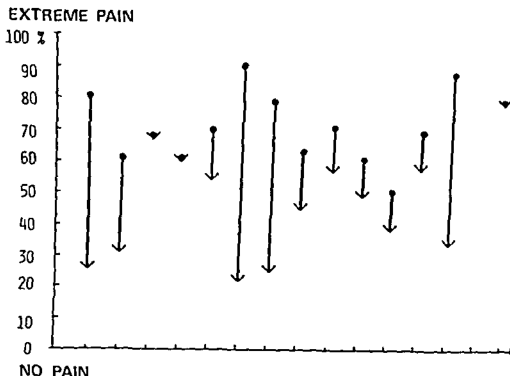


Figure 2 Comparison of the degree of pain before and after treatment • – pain before treatment, ⌄ – pain after treatment

DISCUSSION

Statistical analysis (principal component analysis) of the relationships between the different types of pain showed that pain on standing and pain at rest are the two most significant features, since they cover 80 per cent of all information obtained from this investigation In assessments of this type, therefore, it is probably sufficient to measure these two characteristics

As in earlier reports in the literature on the effect of this treatment we had no controls, and it is therefore difficult or impossible to say with certainty whether the improvement noted is due to a pharmacological effect on the inflammatory process in the dural sac, or whether improvement can be attributed to a placebo effect Having regard to the particularly chronic and severe nature of the cases in question, however, and also to the fact that they had not previously responded to any form of treatment, it may be postulated that the result is at least partly due to pharmacological effects Nevertheless, since there are few if any alternatives it should be worth trying in selected cases

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Acta orthop scand 47, 391–396 1976

INTRASPINAL TUMOURS IN THE FIRST TWO DECADES OF LIFE

Clinical and Radiological Features

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Twenty eight patients with spinal tumours (11 malignant and 17 benign) detected in their first two decades of life have been reviewed Twenty six of the 28 patients had neurological disturbances, and a significant difference in the duration of debut symptoms in the benign and malignant groups could be demonstrated X ray survey was positive in 11 cases in the benign group and in three cases in the malignant group

Key words tumour intraspinal tumour, malignant tumour benign tumour tumours in childhood

Accepted 21 iii 76

Spinal tumours in adolescence are rare and the condition is often overlooked Early diagnosis and surgery are important to avoid the neurological consequences of growth of an intraspinal tumour The purpose of this study was to investigate

1 The diagnostic value of early symptoms and physical signs
2 The diagnostic value of primary X ray findings
3 The histological type and survival rate

PATIENTS AND METHOD

Twenty-eight patients

The records were reviewed with reference to the duration of the primary complaints the survival rate and the histological typing

Protein content in the spinal fluid was noted

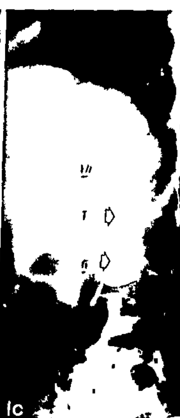
All X rays were reviewed All tumours had been verified by *histology All 17* benign tumours had been operated on 14 with total removal of the tumour Nine of the 11 malignant tumours were operated on and in seven *cases surgery* was followed by irradiation therapy

RESULTS

The age and sex distribution can be seen in Table 1, the topography of malignant and benign tumours is shown in Tables 2 and 3, the primary complaints and primary findings can be seen in Tables 4 and 5 The histological classification is shown in Table 6 and the mean duration of debut symptoms and the survival rate in Table 7


Ia


Ib


Ic


Id


Ie

Table 1 Age and sex distribution

	Benign	Malignant
> 10 years	9	5
< 10 years	8	6
♂ 13		
♀ 15		

Table 2 Localisation of the 28 intraspinal tumours

	Benign	Malignant
Cervical	2	2
Thoracic	5	5
Lumbar	8	3
Sacral	2	1
Total	17	11

DISCUSSION

An early symptom was local or radiating pain, less commonly weakness in a limb or paraesthesia, and there was a significant difference in the duration of debut symptoms in benign and malignant tumours, in contrast to the findings in bone tumours of the spine (P Thommesen & J O Poulsen, *personal communication*) Neurological signs of intraspinal lesions were found in nearly all cases and corresponded to those found by other authors (Ingraham 1938, da Roza 1964, Stookey 1928)

It is remarkable that so many of the patients had severe neurological damage at the time when the condition was diagnosed and that nine of the eleven patients

Figure 1

a Boy 1 year of age with minor neurological signs Notice the slightly enlarged interpedicular distance in the first lumbar vertebra The patient was not treated at this time

b–c Same case as a. Three years later the boy was readmitted (now 4 years old) Scoliosis was present and there were radiological signs of a large but slow growing intraspinal tumour in the upper lumbar and lower thoracic region A ganglioneurinoma was partly removed by surgery

d Four year old girl with Recklinghausens Neurofibromatosis suffering from lumbar pain and irradiating pain in the right leg The surgeon removed a neurofibroma growing in the space under the right fourth pedicle The postoperative X ray shows the marked asymmetry of the pedicles of the fourth lumbar vertebra which might be a sign of the tumour

e Same case as d showing a preoperative myelography which demonstrated the upper border of the tumour

Table 3 Surgery

	Benign tumours	Malignant tumours
Operated cases	17	9
Intradural	5	4
Intramedullar	3	1
Extradural	9	6

Table 4 Primary symptoms

	Benign tumours	Malignant tumours
Local pain	5	5
Radiating pain	7	1
Paraesthesia	2	4
Weakness	6	7
Sphincter disturbances	4	4

Table 5 Physical signs and investigations

	Benign tumours	Malignant tumours
Minor neurological signs	9	2
Major neurological signs	6	9
Scoliosis	10	3
Positive X ray survey	11	3
Elevated protein content in spinal fluid	8	3
Myelography performed	14	9

The neurological signs included motor, sensory, tactic and reflex disturbances and were called minor neurological signs when the function of the patient was slightly disturbed and major neurological signs when the patient was severely disabled and confined to bed

Table 6 Classification of the 28 intraspinal tumours

	Benign	Malignant
Primary tumours		
Meningeoma	1	
Neurinoma	8	1
Dermoids	7	
Teratoid tumour		1
Sympathicoblastoma		3
Glioma		1
Astrocytoma	1	
Secondary to other CNS tumours		
Plexuspapilloma		1
Retinoblastoma		1
Medulloblastoma		1
First manifestation of systemic diseases		
Lymphosarcoma		1
Leukaemia		1
Total	17	11

Figure 2

a Thoracic hourglass shaped neurinoma with calcification and deplacement of structures in the mediastinum

b Same case as a Tomography clearly demonstrates the erosion of the seventh left pedicle indicating intraspinal distribution of the tumour

c Typical hourglass shaped neurinoma at the sixth thoracic segment with a marked scoliosis

d same case as c A tomogram demonstrates the deformation of pedicles and the extraspinal extension

in the malignant group were confined to bed because of severe neurological symptoms at the time of admission to hospital

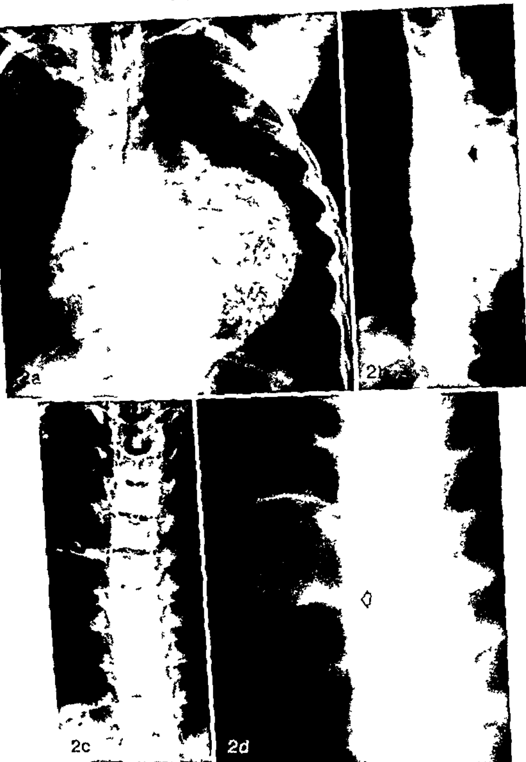
Scoliosis was a rather common sign but was mostly found at the X-ray survey (Banna & Gryspeerdt 1971) Positive X-ray findings were seen in half of the cases showing characteristic signs of intraspinal space occupying lesions as desribed by Friedmann et al (1972) and Hinck et al (1966) The radiological signs were most frequent in the group of benign tumours

In cases where the spinal fluid was analysed, this was of diagnostic value Often the radiological and clinical features were so characteristic that no spinal fluid was taken When myelography was performed it showed the location and in some cases the extent of the tumours

In contrast to other studies (Friedmann et al 1972, Hamby 1944, Lombardi & Passerini 1961) there is a rather high frequence of neurinomas and a rather low frequence of gliomas in this material The dermoids were the most frequent tumour type in the first decade of life often following previous meningitis The survival rate was rather high for the benign group The survival rate in the malignant group was reasonable follow

Table 7 Mean duration of debut symptoms and survival rate

	Mean duration of debut symptoms	Mean survival	Mean observation time
Benign tumours (17 patients)	18 months (min 1 5 months, max 10 years)	1 patient died after 9 months	16 patients alive: 4 years (min 1 year, max 10 years)
Malignant tumours (11 patients)	1 8 months (min 0 5 months, max 6 years)	6 patients have died: 12 months (min 0 25 months, max 4 8 years)	5 patients alive: 3 years (min 1 year, max 5 years)


2a
2b
2c
2d

ing surgery combined with irradiation therapy and chemotherapy depending on the histological diagnosis

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Acta orthop scand 47, 397–402, 1976

OPERATIVE TREATMENT OF SCOLIOSIS WITH THE HARRINGTON INSTRUMENTATION TECHNIQUE

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Preliminary results of treatment of scoliosis with the Harrington instrumentation technique in 80 patients are presented The curve correction at operation averaged 43 4 per cent with the best results being achieved in idiopathic single curves (49 3 per cent) Most of the patients had been treated conservatively for a long time prior to operation, and the curves were rather stiff The initial loss of correction was 3 2°, and the overall loss at 2 years postoperatively averaged 6 5° in 28 patients Complications occurred in 22 5 per cent of the patients, most often at the upper hook site Serious complications were rare It is concluded that the Harrington instrumentation technique is an effective means of treatment of scoliosis

Key words scoliosis, operative treatment

Accepted 3 iii 76

The first spinal fusion for scoliosis was done by Hibbs in 1914 (Hibbs 1924) At Sophies Minde Orthopaedic Hospital posterior spinal fusion including the transverse processes and the intervertebral articular facets has been a routine procedure since 1952 Postoperatively the practice has been to encourage early ambulation in a correcting plaster jacket applied 14 days after the operation (Alvik 1964)

With the Harrington technique (Harrington 1962) an internal correction and fixation is possible This method has now [illegible] ysiotherapy has been attempted The purpose of the present paper is to present the preliminary results

MATERIAL AND METHODS

The material comprises the first 80 patients operated with the Harrington technique, using the distraction instruments only Indications for surgery in idiopathic scoliosis have been thoracic or thoraco lumbar curves of 50° or more, and lumbar or thoraco lumbar double-primary curves of 60° or more In congenital and neuromuscular scoliosis a more individual evaluation has been made Preoperative A-P roentgenograms were taken with the patients standing and used for postoperative comparisons To judge the flexibility of the scoliosis another roentgenogram with traction in the standing position was taken The curves were measured by Cobb's technique Preoperatively the curves were mobilized by the physiotherapists by *daily* stretching and passive bending for a period of about 14 *days* The patients were also given breathing exercises and were drilled in the postoperative *treatment* regime which was the same as described by Elfstrøm & Nachemson (1973)

The operation was performed in one session with the patient in the knee-elbow position (Alvik 1964) The upper hook was *inserted into* the intervertebral joint at the upper end of the



Figure 1 a A girl, 14 years old with an idiopathic scoliosis The curve right thoracic is 77°

curve and the distal hook was usually placed on the lamina of the second vertebra below the end of the curve, except in lower lumbar curves where the lamina of the first vertebra below was chosen A posterior fusion including all posterior elements between the hooks was also performed After inserting the rod the curve was corrected with the force indicating distractor (Nachemson & Elfstrom 1969) applying a force of about 40 kilopond Only one rod was inserted in double as well as in single curves (Figure 1) A large amount of bone graft was used usuall both from the iliac crest and from the bon bank, in a few cases autogenous or homogenou



Figure 1 b Supine roentgenogram made at the end of the operation shows correction to 30°

bone only was used The wound was closed tightly without drainage except on the donor side of the iliac crest. At the end of the operation a roentgenogram was taken with the patient in the supine position The amount of correction of the scoliosis obtained by the operation was defined as the difference in degrees between this and the preoperative roentgenogram taken in the standing position

Antibiotics were not used routinely but all patients were given sulphonamides from the third day postoperatively to prevent urinary infection from continuous bladder drainage during the first week

Postoperatively the patients were nursed in the supine position without external support for 4 to 5 weeks those with the lower hook site on the third lumbar vertebra or below for the longest period Before ambulation the patients were supplied with a well fitted Milwaukee brace, and before discharge a standing roentgenogram was taken The Milwaukee brace was worn day and night for 11 months, followed by a weaning period of 6 months

RESULTS

The aetiology of the scoliosis, the sex distribution of the patients and the type of curves are given in Tables 1 and 2 The percentage of females was highest in the idiopathic group which comprised 64 of the 80 patients The majority of the patients (51) had thoracic single curves Thirteen had thoraco lumbar double curves When calculating curve correc-

Table 1 Aetiology of the scoliosis and the sex distribution in 80 patients treated with the Harrington technique

Aetiology	Female	Male	Total
Idiopathic scoliosis			
Infantile	2	2	4
Juvenile	15	3	18
Adolescent	33	9	42
	50	14	64
Congenital	5	4	9
Miscellaneous *	4	3	7
Total	59	21	80

* Neuromuscular neurofibromatosis and Marfan's syndrome

Table 2 Curve type in 80 patients with scoliosis treated with the Harrington technique

Thoracic	single curves	51
Thoraco lumbar	single curves	15
Lumbar	single curves	1
Thoraco lumbar	double curves	13
Total		80

tion both curves were included Thus a total of 93 primary curves were investigated

The mean age of the patients at operation was 15 years 3 months (range 9–35 years) Only three were more than 20 years old The mean age when the spinal disorder was discovered was 8 years 9 months, and the mean age when the patients were referred to our hospital was 11 years 2 months All but ten patients had been treated conservatively prior to operation, 46 for more than 1 year (average 4 years 9 months)

The mean curvature was 71 6° (Table 3) The mean correction on the radiograms taken with traction was 9 7° Physiotherapy increased this correction by an average of 3 8° Although small, the difference is significant, $P < 0\ 01$ The curve correction by operation was 31 1°, 43 4 per cent, in the idiopathic group 46 8 and in the congenital group 29 1 per cent Comparable height measurements before and after operation were available in 37 patients The average increase in height was 3 8 cm (range 1 5–8)

The initial loss of correction, i e , loss before discharge, was 3 2° (Table 4), and the overall loss when the weaning period of the Milwaukee brace started at 11 months after operation was 5 6° The loss of correction 2 years after operation was 6 5° (28 patients) which gives a final correction of 34 5 per cent

On the average, 11 vertebrae were fused (range 8–14) Mean operation time was 3 hours 20 min (range 2 20–4 20) and average blood replacement during

Table 3 Curve correction with the Harrington technique in 80 consecutive operations for scoliosis (Mean ± S D)

Aetiology	Patients no	Curves no	Preoperative curves: Standing degrees	Preoperative curves: Correction by traction standing degrees	Curve correction by operation: Degrees	Curve correction by operation: Per cent
Idiopathic:						
All curves	64	75	69.2 ± 14.9	9.8 ± 8.1	32.4 ± 8.8	46.8
Single curves	53	53	68.2 ± 15.4	11.1 ± 8.6	33.6 ± 8.5	49.3
Congenital:						
All curves	9	10	82.6 ± 19.8	10.6 ± 7.9	24.0 ± 11.1	29.1
Single curves	8	8	87.0 ± 19.1	13.3 ± 6.4	26.0 ± 11.5	29.9
Miscellaneous						
All curves	7	8	81.9 ± 26.8	5.8 ± 5.0	27.8 ± 8.3	34.8
Single curves	6	6	79.5 ± 31.3	7.7 ± 6.0	33.8 ± 8.9	42.5
Total						
All curves	80	93	71.6 ± 17.2	9.7 ± 8.0	31.1 ± 9.4	43.4
Single curves	67	67	71.4 ± 18.5	11.2 ± 8.2	32.4 ± 9.2	45.4

and after operation was 1156 ml (range 300–2700)

Complications occurred in 18 patients (22.5 per cent) (Table 5) In five, one having a double curve, hook displacement or laminar fracture occurred during the first postoperative weeks The initial loss of correction in these patients varied from 14 to 23° One patient was reoperated after 18 days A laminar fracture was found at the upper hook site Proximal displacement of the rod in the upper hook (half notch) occurred in three patients, two while ambulant in the Milwaukee brace The correction loss in these cases varied between 7 and 17°

Neurological complications were encountered in two patients A 13-year-old girl with a slight heredo-ataxia and a thoracic curve of 61°, reduced to 45°, had for the first 2 months after the operation faecal and urinary incontinence Her complaints regarding the nervous disorder increased somewhat after the operation The other patient was a 17-year-old boy with a left sided idiopathic thoracic scoliosis of 115° The scoliosis was reduced to 66° Since the operation he has had hyperhidrosis and gooseflesh reaction in a segmental, 15 cm wide belt on the right side of the thorax corresponding to the fourth thoracic nerve segment

Table 4 Loss of correction after surgery in scoliosis using the Harrington technique (Mean ± S D)

Aetiology	Initial loss degrees	Total loss at 11 months degrees	Total loss at 2 years: Degrees	Total loss at 2 years: No	Residual correction at 2 years after surgery Per cent
Idiopathic	3.3 ± 4.7	5.5 ± 6.2	6.4 ± 6.1	23	37.6
Congenital	2.6 ± 3.2	4.4 ± 5.4	2.0	1	
Miscellaneous	3.0 ± 2.7	6.5 ± 5.0	7.5 ± 9.7	4	25.6
All cases	3.2 ± 4.4	5.6 ± 5.9	6.5 ± 6.3	28	34.5

Table 5 Complications in 80 patients operated with the Harrington technique

Complication	No of patients
Upper hook displacement or laminar fracture	5
Rod displacement in hook	3
Neurological	2
Urinary bladder infection	4
Ureter stone	1
Icterus (unknown aetiology)	1
Pneumonia	1
Wound infection (superficial)	1
Gastro intestinal retention	1

DISCUSSION

The curve correction obtained by the Harrington rod technique in the present material was largest in the idiopathic group, being 49 per cent for single curves The degree of correction obtained in congenital scoliosis was rather small 29 per cent The reason is obviously the presence of anatomical malformations preventing a satisfactory straightening of the curves In idiopathic scoliosis a correction of about 50 per cent is usual (Nordwall 1973) Our results are in agreement with this

Most of our patients had been treated conservatively for a long time during which their curves had increased (average 29.1° ± 22.1°) and stiffened Preoperative mobilization with physiotherapy had little effect on the flexibility of the curves The loss of correction after operation was within reason (Table 4) and in agreement with other reports (Leider et al 1973 Nordwall 1973)

The complication rate in the present series 22 5 per cent as well as in other series (Dickson & Harrington 1973 Leider et al 1973 Nordwall 1973) is high Two of our patients had neurological complications MacEwen et al (1975) reported an incidence of neurological complications most often involving the spinal cord, of 0 7 per cent in a large series Complications at the hook sites laminar fractures, hook displacement and rod displacement in the hook, occurring in 10 per cent of our patients, led to an obvious loss of correction Displacement of the hook seems to be relatively frequent even in the hands of experienced surgeons (Leider et al 1973, Dickson & Harrington 1973) Two of our patients with this complication got out of bed at night shortly after surgery and a third caught pneumonia accompanied by severe coughing during the first postoperative week The small degree of loss in correction occurring in most curves is probably due to erosion at the hook sites A snugly fitting Milwaukee brace or plaster cast is essential to relieve load on the rod and thus reduce erosion Loss of correction may also be caused by continual growth of the spine before fusion is consolidated Complications are more frequent in younger children Letts & Bobechko (1974) stressed that Harrington instrumentation is contraindicated in children under 10 years Only one of our patients belonged to this group

Other complications including four urinary bladder infections responded promptly to adequate medical therapy Antibiotics were not given prophylactically despite the fact that all operations lasted for more than 2 hours However, there was only one case of superficial infection, and this was without influence on the further course of the treatment Nor were wound haematomas any problem So far we have not had any cases with pseudoarthrosis but only 28 patients have been observed for a period of 2 years or more

The average final results of spinal fusion in our earlier series of idiopathic scoliosis without internal correction, was a curve of the same magnitude as before surgery (E Ronglan, personal communication) Similar results are obtained with conservative treatment (Nordwall 1973)

With the Harrington instrumentation technique the initial correction is very good and the late loss of correction tolerable The total complication frequency is high, but serious complications are relatively rare considering the scope of the operation

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Acta orthop scand. 47, 403–405, 1976

THE CE ANGLE OF NORMAL HIPS

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The Center Edge angle (CE angle) of Wiberg was measured in normal hips in patients between 8 and 75 years of age Males and females were recorded separately Means and standard deviations are presented here The angle increased with growth up to adult age, and then only slowly In children only values below 15° can be classified as abnormal

Key words acetabulum, congenital, dislocation, hip joint

Accepted 3 v 76

The Center Edge angle (CE angle) was introduced by Wiberg (1939) as a measure of acetabular development and/or the degree of displacement of the femoral head It has been employed almost exclusively in relation to congenital dislocation of the hip and the CE angle here distinguishes normal and so-called dysplastic hips Wiberg (1939) stated that values over 25° were normal in adults and that values between 20° and 25° were uncertain This has been confirmed in other investigations (Severin 1941, Wiberg 1944, 1953 Wynne Davies 1970, Fredensborg 1976) In children, however, there are different opinions about normal values

The aim of the present study was to investigate the variations in the CE angle with age and sex

MATERIAL AND METHODS

The CE angle is the angle formed by a vertical line through the center of the femoral head and a line from the center through the lateral edge of the acetabular roof (Figure 1) The center of the femoral head is found with the aid of concentric circles on a transparent sheet. In young children, however, the ossified part of the capital epiphysis is flat which makes determination of the center somewhat difficult From the age of 8 the center can be measured with accuracy

Standard pelvic radiograms of normal hips in patients who had been radiographed because of trauma or transient hip pain were used Ages

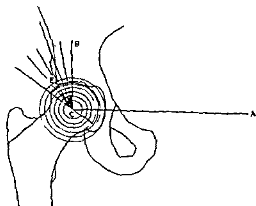


Figure 1 The CE angle according to Wiberg (1939) From the center (C) of the femoral head a line (C–A) is drawn through the center of the head of the opposite side Perpendicularly to this line and through the center (C) the line (C–B) is raised The CE angle denotes the angle between the line C–B and a line from C to the acetabular edge (E)

With the Harrington instrumentation technique the initial correction is very good and the late loss of correction tolerable. The total complication frequency is high, but serious complications are relatively rare considering the scope of the operation.

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ranged from 8 to 75 years Each group included 20 hips (10 patients) of both sexes

RESULTS

Since there was no difference between left and right the sides were pooled The CE angle was found to increase up to the age of 15 (Figures 2 and 3) After this age there was only a slight increase The curve was almost identical in both sexes The standard deviations indicate a considerable variation both in children and in adults

DISCUSSION

The CE angle is an excellent method of studying the development of the hip joint in radiograms It is simple and unlike other measurements (Bruckl et al 1972) requires only a few lines to be drawn on the radiogram (Catteral 1968)

The results of the present investigation confirm previous findings CE angles exceeding 25° in adults are normal and values between 20° and 25° are borderline In children under 15 years of age, however, 20° or more should be considered as normal and values between 15 and 20° as uncertain

The small increase in the CE angle after maturation is not accounted for It may, however, be explained either by marginal, undetectable osteophytes or a decreasing joint space

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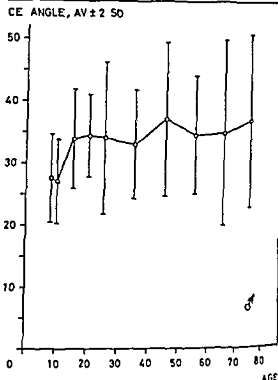


Figure 2

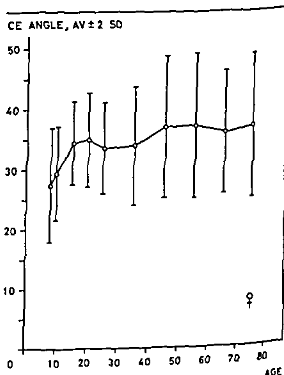


Figure 3

Figures 2 and 3 The CE angle of normal hips in males (Figure 2) and females (Figure 3) Mean values and two standard deviations

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Acta orthop scand 47, 406–409, 1976

COMPRESSION AND THE OSTEOTOMY GAP

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The existence of a clearly visible osteotomy gap by optimal roentgenography even in cases where high compression had been applied is exemplified One case of fracture of the osteosynthesis material used in a medial displacement osteotomy is illustrated It is suggested that this and similar accidents are sometimes consequences of imperfect surface contact at the operation, visible only by central beam radiographs

Key words compression, osteotomy, radiography

Accepted 27 ix 76

An osteotomy operation, i e division of a bone, is carried out for various reasons in order to obtain lengthening, shortening, angulation, rotation, or other displacements of a bone, or to amputate In experimental orthopaedic surgery the procedure is performed primarily for fracture studies or investigations concerning fracture fixation devices

The instrument of choice for the procedure is, of course, the saw This basic tool exists in various shapes and functional build up, from the carpenter's simple blade saw, still much used, to the sophisticated, thin, ultra rapid, cooled, oscillating or rotating air-driven saw Between these two extremes is found the classic Gigli saw The problem of instrumentation is the same in clinical and experimental surgery The instrument must not destroy the adjacent bone or soft tissues, mechanically or thermically It should be easy to use and it should produce an osteotomy line according to the plans of the surgeon, which usually include the creation of congruous osteotomy surfaces

Under optimal experimental conditions it may be possible to create an almost invisible line of contact after bridging the osteotomy line with a plate, especially if compression is used, either by means of a special compressor (Muller et al 1970), or a special design of the plate and the screws (Bagby 1958, Perren et al 1969), or by using a guide that compensates for the length loss of the osteotomy when the plate is applied (Hutzschenreuter et al 1969)

Provided the osteotomy surfaces are parallel to each other and that forces are acting uniformly upon the surfaces, compression minimizes the grains and corners of the bone ends, created by the irregular movements of the saw, heterogenous bone resistance, changes of speed and pressure of the instrument, etc Bone is, however, very resistant to static compression Large loads are needed to produce impaction and uniform contact even between very slightly incongruent surfaces

Figure 1 illustrates an experimental situation, where the denuded radius of a

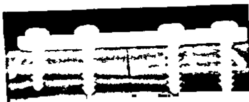


Figure 1 This illustrates an osteotomy of a dog's radius fixed and compressed according to the AO technique with a force exceeding 100 kp The screws do not touch the ulna

dog, linked by the interosseous membrane to the intact ulna, was osteotomized with a Stryker saw (blade thickness 1 mm) During the procedure two rubber bands were strained between Kirchner wires, producing a tension force of less than 0 5 kp This force was sufficient to produce immediate contact between the osteotomy surfaces after sawing This force thus compensated for the retaining force of the parallel, intact ulna The series of experiments was performed under optimal conditions In three instances the osteotomy surfaces were compressed, according to the AO technique, by forces exceeding 100 kp

Figure 2 illustrates a similar experimental situation, where a dog's radius, also stripped of its muscles and linked to the intact ulna, was osteotomized and the osteotomy surfaces compressed A new device for fracture fixation was used in six such experiments (Edeland 1974) The applied compression force in each case was less than 25 kp

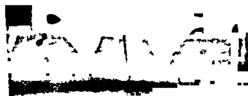


Figure 2 This illustrates a stabilized osteotomy of a dog's radius compressed by an experimental device, with a force not exceeding 25 kp

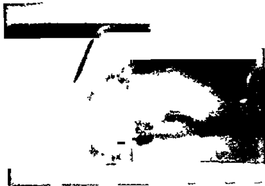


Figure 3 Counter light photography of an osteotomy maximally compressed with the device of Figure 2

Roentgenographically, a narrow osteotomy gap is visible, using both kinds of devices The gaps are wider than should be expected after inspection of the osteotomy lines by gross examination and by counter light photography (Figure 3)

On a gracile, denuded extremity, placed immediately upon the X ray film, even rather substantial deviations from the optimal projection may reveal the osteotomy gap clearly In a clinical situation, the angle of the central X ray beam may be more critical, and the optimal projection difficult to obtain Soft tissues may hide the level of the osteotomy, and the direction of the osteotomy line may be oblique In most cases the surgeon has a good chance to inspect much of the circumference of the osteotomy line, and to palpate the rest

In intertrochanteric displacement osteotomies particularly, the fullest possible support is essential, as only parts of the cortical circumferences are geometrically in apposition, and also because early joint movements are encouraged Movements occurring in the osteotomy cleft will cause resorption of the supporting surfaces and successively increase the freedom of movement of the bone ends This may cause fractures of the osteosynthesis material used

In the illustrated case (Figure 4) an





Figures 4 and 5 X ray pictures fro i an intertrocl ai ter c lisplace ent osteoton y a sl ort j r d postoperatively (Figure 4) and 6 mo ths postoperati ely (F gure 5) Figure 4 sho vs that the projection was not parallel to the osteoton y

intertrochanteric displacement osteotomy with compression fixation was per formed to relieve the symptoms of pain from a hip joint with degenerative osteoarthritic changes The passive and active ranges of motion of the hip pre operatively were slightly reduced partic ularly rotation and abduction This and a suboptimal contact between the osteot omy surfaces may have caused the break of the plate blade in the trochanter (Figure 5)

Similar problems have been reported in several cases of osteotomies of the proximal femur An incidence as high as 20 per cent of non union and pseud arthrosis has been reported Displace ment of the distal fragment too far medially is supposed to be the most im portant factor in the occurrence of non union Movements at the osteotomy site bridged by the fixation device may pro duce bone resorption at the purchase of the blade and at the screws This de creases the stability of the osteosynthesis and increases further bone resorption in a vicious circle

The importance of achieving maximal contact and impaction of the osteotomy surfaces by compression is certainly valid in all osteotomy operations where primary bone healing is the aim These conditions could only be judged by roent genography optimal for the visualization

of the osteotomy gap i e by X ray beams parallel to the osteotomy cleft Optimal roentgenographical documentation of the osteotomy line immediately after fixation is essential for evaluation of the prospects of healing of the osteotomy

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Acta orthop scand 47, 410-414 1976

PERTROCHANTERIC FRACTURES OF THE FEMUR TREATED WITH A KÜNTSCHER TROCHANTER NAIL

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Thirty nine patients with pertrochanteric fractures were treated with the Küntscher trochanter nail Six were males and 33 females Their mean age was 76 years Excellent or good results of treatment were recorded in 25 cases and good union of the fracture was noted in 19 patients within 4 months and in 15 cases as early as 2 months after the operation The primary mortality rate was of the same order as with other methods of nailing 15 per cent in this series The operation is easy and short, and is suitable at least for stable pertrochanteric fractures of elderly patients

Key words trochanteric fractures, fracture fixation intermedullary internal

Accepted 28 ix 76

The choice of the method of internal fixation of pertrochanteric fractures is in the first place dependent on the type of fracture (Riska 1971), while the after-treatment has to be planned according to the method employed Early mobilization is essential in the treatment of patients with pertrochanteric fractures in order to avoid complications, but the duration of the operation is important too In 1970, Küntscher presented a new method of internal fixation of pertrochanteric fractures which enabled the patient to become ambulant very soon after the operation and permitted early weightbearing The technique was easy and the operation was rapid (Küntscher 1970 a, b) Because of this, some centres soon adopted the method (Giebel 1970 Hansen & Helland 1972, Koch & Zelder 1972) In 1973 our clinic published a preliminary report of good results (Riska & Lyytikäinen 1973) The method seemed to be suitable for certain types of pertrochanteric fractures This motivated the follow-up of these patients and a report of late results

MATERIAL AND METHODS

Material

The series consists of the first 39 consecutive patients with pertrochanteric fractures treated with a Küntscher nail The nail was inserted through the medial femoral condyle after reduction of the fracture on the operating table under general anaesthesia Six patients were male and 33 females They ranged in age between 51 and 90 years with a mean of 76 years Seven of the patients had a comminuted type of pertrochanteric fracture (Table 1)

Table 1 Patients with pertrochanteric fractures treated with a Küntscher nail

Sex	Number of patients	Average age (years)	Type of fracture	
			Pertrochanteric	Pertrochanteric comminuted
Male	6	67	6	0
Female	33	77	26	7
Total	39	76	32	7

Preoperative treatment

Twenty six patients were treated with traction before nailing and prophylactic anticoagulation treatment was given to 29 patients Because of their many concomitant diseases most of the patients required an average of 4 days' pre operative treatment for high blood pressure heart conditions chronic renal conditions and infections of the respiratory tract

Operative technique

The operative fixation of the fracture was carried out with the pertrochanteric Küntscher nail (Figure 1) under general anaesthesia The fracture was reduced by extension abduction and internal rotation under the control of an X ray television screen Special attention was paid to reconstruction of the calcar femorale and a slight valgus position seemed to be favourable for the procedure A curved guide pin was introduced through a small incision at the medial femoral condyle and pushed up to a distance of 1 2 cm from the surface of the femoral head Along this guide pin the curved trochanter nail 10 mm in diameter was intro duced into the medullary cavity and hammered in place, and then the pin was removed A small flat pin was inserted through the distal hole in the nail to prevent extrusion of the nail. Half an hour was usually enough for the nailing proce dure In some cases the nail perforated the lateral cortex of the femoral neck without any damage being done but in these cases the nail was removed after the fracture had healed

Table 2 Pertrochanteric fractures treated with a Küntscher nail

Mobilization after operation	Number of patients
On the 1st day	17
2nd day	12
3rd day	2
4th day	1
5th day	1
6th day	1
7th day	1
10th day	1
Total	36

Aftertreatment

Seventeen patients were mobilized on the first day and 12 on the second day after the oper ation Full weightbearing on the operated limb was allowed from the beginning For five pa tients the mobilization was started later because of their poor general condition (Table 2) Three patients died on the first postoperative day Twenty six patients left the hospital within 4 weeks but five of them subsequently died (Table 3) For 13 patients the hospital treatment lasted longer

Complications

The primary mortality rate was 15 per cent (Table 4) Three patients died of pulmonary thrombo-embolism on the first day after the operation two of heart infarction within 4 days and one of apoplexy 32 days after the operation Six patients died later at home No infections were recorded

Table 3 Pertrochanteric fractures treated with a Küntscher nail

Duration of hospital treatment	Number of patients
Less than 2 weeks	10
2– 4 weeks	16
4– 6 weeks	9
7 10 weeks	4
Total	39



Table 4 Pertrochanteric fractures treated with a Küntscher nail

Follow up time	Number of patients
7–11 months	3
12–17 months	7
18 23 months	2
2 years	8
Over 3 years	7
Primary mortality (within one month)	6
Insufficient follow up (because of death)	6
Total	39

Follow up

In all the cases for which the follow up period was adequate, good union of the fracture was verified within 4 months, and in 14 cases within 2 months Nine patients were followed up for over 1 year, 15 for over 2 years For six patients the follow up period was insufficient because they died within 1 year after the operation (Table 4)

Table 5 Results and complications of the treatment of 39 patients with a Küntscher nail

		Number of patients
Results		
Excellent		18
Good		7
Fair		2
Insufficient follow up (because of death)		12
Total		39
Complications		
Mortality		12
Primary	6	
At a later stage	6	
Thrombo embolic disease (all leading to death)	3	
Infection		0
Total		12

Figure 1 Radiograph 1 year after an operation on a 65 year old woman with a pertrochanteric fracture of the femur treated by a Küntscher trochanter nail inserted through the medial femoral condyle

RESULTS

For 18 patients the result of the treatment was considered to be *excellent*, there was good union of the fracture and they walked without a limp The result was *good* for seven patients i e good union of the fracture, but the patient had to use a walking stick and the range of movement of the hip joint was slightly reduced (Table 5) For two patients the result was *fair* there was pain in the hip joint and the fracture had united in a poor position in one case because of a comminuted pertrochanteric fracture and in the other because the nail perforated the femoral cortex The result of treatment could not be evaluated in 12 cases because of the insufficient follow up period

DISCUSSION

In spite of the advanced age of the patients 26 could be sent home within 1 month 25 of these cases with excellent or good results The result was excellent in four cases and good in one case with comminuted pertrochanteric fracture although the fractures were regarded as unstable Union of the fracture occurred in 14 cases within 2 months which is rarely seen with other methods of nailing The introduction of the nail in a position remote from the fracture site is probably responsible for this rapid consolidation Additionally no incision was made at the fracture site This may accelerate the healing process of a fracture in the trochanteric region The forces acting in the proximal part of the femur follow the same line as the nail (Hansen & Helland 1972) Thus several facts speak in favour of this nailing method at least for stable pertrochanteric fractures In some cases there was trouble from the knee joint but this was easily treated by removing the nail later Problems often arise in the treatment of elderly patients with hip fractures, one of them being prolonged hospitalization Of our series however, 26 patients went home within 1 month of surgery which is a short hospital stay (cf Riska 1970b) The primary mortality rate was high, but the same is true of other methods of nailing (Riska 1970 a) In most cases concomitant diseases seem to be the usual cause of fatal outcome soon after the operation, this was also true of our series Three patients died of pulmonary thrombo-embolism and two of heart infarction Thus in this age group the prevention of primary deaths is hardly possible

The results of the treatment of these 39 patients with pertrochanteric fractures indicate that it is possible to achieve good stability of the fracture with the Kuntscher trochanter nail The operation is easy and short Early mobilization of the patient is possible and full weightbearing of the operated extremity is allowed on the first day after the operation With this method of internal fixation it is possible to prevent, at least to some extent, the usual postoperative complications, and to shorten the hospital stay for elderly patients But the primary mortality rate seems to be of the same order as with other methods of internal fixation of pertrochanteric fractures

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Acta orthop scand 47, 415–418, 1976

A NEW DESIGN OF THE CHRISTIANSEN ENDOPROSTHESIS

Report of Two Cases in which Separation of the Two Components of the Prosthetic Head Occurred

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Primary prosthetic replacement in elderly patients with displaced intracapsular fracture of the femoral neck has been used during the last few years with encouraging early results The prosthetic device preferred has been Christiansen's endoprosthesis During the past year a new type with separable plastic head and metallic cap has been used This modification has resulted in the occurrence of a previously unknown complication a separation of these two parts necessitating reoperation and insertion of a new head piece The possible mechanisms causing this separation are discussed

Key words hip joint joint prosthesis orthopaedic equipment, prosthesis design

Accepted 18 v 76

Since 1970 we have used the "trunnion-bearing endoprosthesis of Christiansen for routine prosthetic replacement in patients over 65 years of age with displaced intracapsular fracture of the head of the femur The preliminary results have been satisfactory (Soreide et al 1975)

We would like to present a previously unpublished complication In two patients operated on and fitted with Christiansen s endoprosthesis a dislocation of the plastic head from the metallic cap necessitated reoperation and replacement of the dislocated head

CASE REPORTS

Case 1 The patient was a 78 year old woman who in January 1975 sustained a displaced intracapsular fracture of the femoral *head She* was given operative treatment with reduction and internal fixation Three months later X ray investigation showed a secondary displacement of the operated fracture The nail was removed and a Christiansen endoprosthesis inserted Recovery and rehabilitation after the operation were normal and the primary result satisfactory Nearly 4 *months after* the operation the patient was admitted again this time because of acute pain and difficulty in walking X ray revealed a *dislocation* of the head piece of the prosthesis which was initially suspected to be a luxation in the "*trunnion bearing*" connection (Figure 1) An attempt at non operative reduction failed At the subsequent operative exploration no dislocation was found in the "trunnion bearing" junction but the plastic head had slipped out of the covering metallic cap It was impossible to reduce the dislocation because of a disproportion *between* the two parts possibly due to a swelling of the plastic head Both head and cap were removed and replaced by a *new piece The* postoperative course was again uneventful and at later visits the patient has been satisfied and objectively has a good functional result

Case 2 The patient was a 75 year old woman At the end of April 1975 she fell on the floor and sustained a severely displaced intracap-

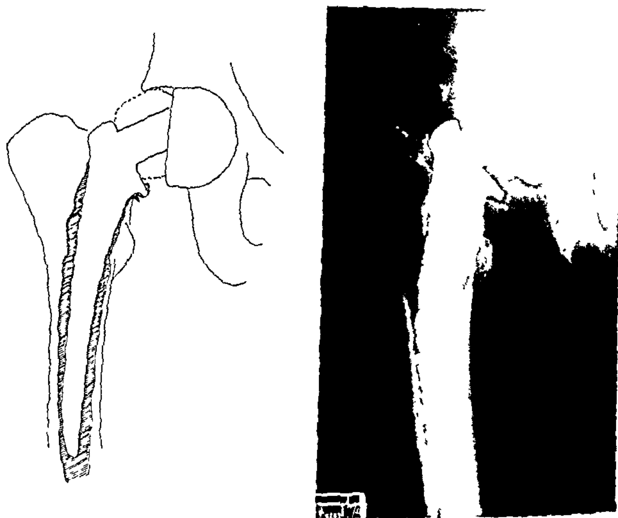


Figure 1 X ray and diagram showing dislocation between the two head pieces the metallic cap separated from the plastic head

sular fracture of the femoral head She was operated on and fitted with a *Christiansen* endoprosthesis and had an initially uncomplicated postoperative course About 4 months later as she was rising from a chair she suddenly experienced severe pain in the operated hip and was later unable to walk X ray investigation revealed a dislocation between the metallic cap and the plastic head No attempt was made to reduce the dislocation non operatively, but at surgery an identical situation to that in Case 1 was found The dislocated plastic head and metallic cap were removed and a new head piece inserted The postoperative course was uneventful and the postoperative result satisfactory

DISCUSSION

The first femoral head prosthesis introduced by Christiansen in 1965 consisted of a shaft made of stainless steel connected through a "trunnion-bearing" with a head piece made of synthetic plastic material (Christiansen 1969) The initial clinical results were satisfactory (Ramstad 1969), but with a longer observation time results were disappointing (Kavli & Sundal 1974, Kavli et al 1975) It appeared that in patients reoperated on or investigated at autopsy a substantial abrasion of the plastic head with deformation and secondary serious reactive synovitis and osteoporosis were found To avoid abrasion the head was then equipped with a steel cap In the original construction the cap was firmly attached to the plastic head Since 1973 this detail has been modified and in the prosthesis

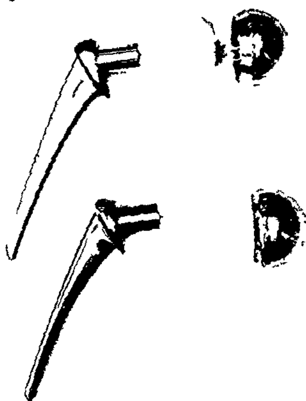


Figure 2 Christiansen's endoprosthesis Above the latest modification with trunnion bearing Delerin head and metallic cap separated Below the original modification of the prosthesis with the cap attached to the plastic head

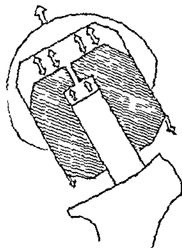


Figure 3 Possible hydraulic mechanism in the system between the trunnion bearing joint and the covering metallic cap Increased pressure occurring in the space between the head and the cap leading to dislocation between the metallic cap and the plastic head

which now prevails the plastic head is separated from the steel cap (Figure 2) This modification has the advantage that the prosthesis pieces may be sterilized in an autoclave Furthermore this modification is supposed to permit some degree of movement between the head and the cap (Christiansen 1974)

The mechanism of dislocation in the above-mentioned cases is uncertain In both patients, however, a clot of fibrin and blood (approx 15 cm³) was found in the bottom of the steel cap It is possible that this clot under certain circumstances has closed the hole in the bottom of the plastic head causing a sort of valve mechanism, letting blood or tissue fluid into the steel cap but not out Furthermore a hydraulic mechanism is possible in the system between the trun-

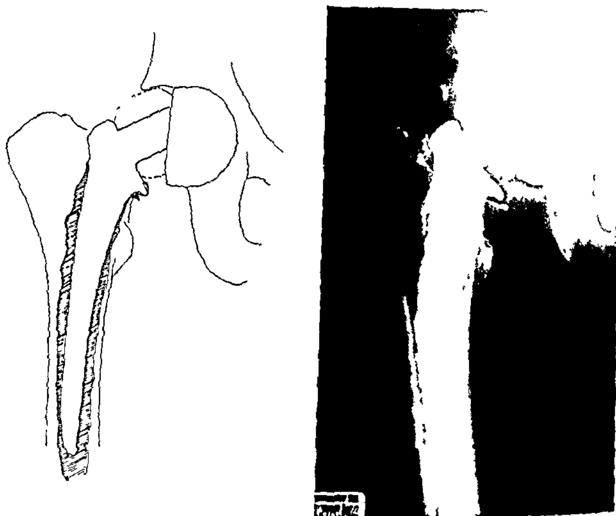


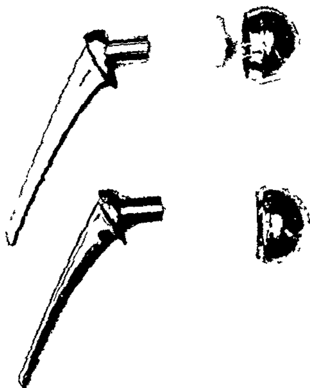
Figure 1 X ray and diagram showing dislocation between the two head pieces the metallic cap separated from the plastic head

sular *fracture* of the femoral head She was operated on and *fitted* with a *Christiansen* endoprosthesis and had an initially uncomplicated postoperative course About 4 months later as she was rising from a chair she suddenly experienced severe pain in the operated *hip* and was later unable to walk X ray investigation revealed a *dislocation between the* metallic cap and the plastic head No attempt was made to reduce the dislocation non operatively, but at surgery an identical situation to that in Case I was found The dislocated *plastic* head and metallic cap were removed and *a new* head *piece* inserted The postoperative *course* was uneventful and the postoperative result satisfactory

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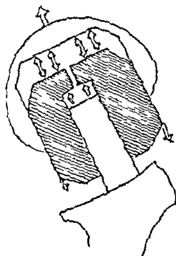


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It is evident that this complication is found only in the latest modification of the prosthesis Though uncommon, this is a serious complication necessitating reoperation in this advanced age group with increased operative risks A firm attachment between the cap and the plastic head prevents this complication and consequently it seems reasonable revert to this original modification

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Correspondence to J H Solhaug, Department of Surgery, Haukeland Hospital Bergen Norway

Acta orthop scand 47, 419–422, 1976

CONGENITAL BIFID FEMUR

B AALAMI-HARANDI & A ZAHIR

Department of Orthopaedic Surgery, Shafa Rehabilitation Hospital,
Jaleh Ave., Teheran Iran

Two identical and unusual cases of congenital bifid femur are described. Both cases were successfully rehabilitated after simple surgery and the fitting of a suitable prosthesis The patients are now able to walk without any form of external support.

Key words femur, abnormality

Accepted 10 ii 76

There have been several reports of congenital anomalies of the femur in recent years Almost all of these have dealt with congenital coxa vara, proximal femoral phocomelia and congenital bowing of the femur As far as we know there have been only two reports of congenital bifid femur in the medical literature (Morris 1958, Cornah & Dangerfield 1974) In this article we describe two cases of congenital bifid femur which were rehabilitated after surgery

CASE REPORTS

Case 1

G.M.R a 9 year old male orphan was admitted to Shafa Rehabilitation Hospital in September 1971 with congenital deformities of the right lower limb, the left foot and the right hand He was unable to supply any information regarding his past or his family history The child has a normal level of intelligence and the following physical anomalies were noted

Right lower limb The distal end of the thigh was widened and of triangular appearance, palpation revealed the distal part of the femur to be bifurcated The terminal portion of the medial branch was easily felt under the skin The lateral branch articulated with a fibula suggesting some form of knee joint There was a flexion contracture of 120° at the articulation. The range of motion of this joint was 20° (from 30° to 50°) and was painless The distal end of the fibula articulated with a rudimentary foot which possessed only the lateral three rays The right hip joint was normal

Left foot This was plantigrade and had six toes the extra toe representing a rudimentary great toe The patient walked well on this foot, using one crutch. He ambulated also without support by walking on his knees

Right hand This hand had a lobster claw deformity, it had good sensation and the child could grasp objects very well

The physical examination was otherwise normal Routine laboratory tests and chest roentgenogram were normal

Case 2

An 18 year-old male was admitted to Shafa Rehabilitation Hospital in July 1974 with congenital deformities of the right lower limb and the left foot His mother stated that his gestation and delivery were normal, she had not taken any drugs during pregnancy and there were no similar deformities in the family The following physical abnormalities were noted during the examination The right lower limb and thigh exhibited exactly the same deformity as in case 1 The knee joint was formed between the lateral branch of the bifid femur and the fibula identical to that seen in the first case The rudimentary foot, however, had only two lateral rays as opposed to three in the first case The hip joint and proximal femur were normal

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A



B



C

Figure 1 Case 1 A Roentgenogram of the right femur before surgery
B Roentgenogram of the right femur after surgery
C The patient after surgery

The left foot This showed absence of the first ray with a small digit, in place of the hallux which was attached on the medial side of the foot and was without any voluntary movement The foot was otherwise plantigrade

The rest of the physical examination was normal The mode of locomotion of this patient was identical to the first case

In both cases surgery was performed on the bifid femur in order to fit a suitable artificial

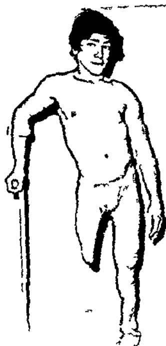
Figure 2 Case 2 A The patient before surgery B Roentgenogram of the right femur before surgery C The patient after surgery



A



B



C

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Operative findings

In both cases the findings were the same There was no intramedullary canal at the level of bifurcation the femur was flattened the



A

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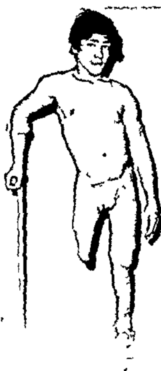
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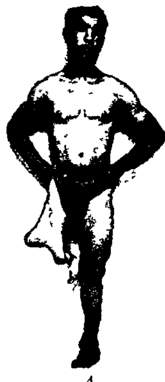


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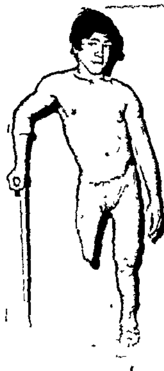
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TREATMENT AND RESULTS

In both cases the lateral branch of the femur (the part articulating with the fibula) was resected at the level of the bifurcation An osteotomy was performed at this level on the medial fork and this portion was realigned with the shaft of the main bone The osteotomy was secured by means of a wire suture and a Kirschner wire The stump was immobilized in a plaster of Paris spica The Kirschner wire was removed at the end of 3 weeks, and the spica at 12 weeks postoperatively when radiological and clinical union had occurred at the site of the osteotomy Both patients have been fitted with a knee disarticulation prothesis and are walking without the aid of crutches No treatment was considered necessary for the so-called normal foot since this was asymptomatic and plantigrade

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Acta orthop scand 47 423–431 1976

EXPERIENCE WITH KNEE SYNOVECTOMY IN NORWICH 1964–1973

DAVID JONES & J G TAYLOR

Department of Orthopaedic Surgery and Rheumatology The Norfolk and Norwich Hospital Norwich England

Thirty six patients (43 knees) who underwent anterior synovectomy for rheumatoid disease between 1964 and 1973 have been personally reviewed The notes and X rays of a further seven patients (10 knees) have been examined

Twenty five per cent of the knees were failures at the time of review but only two were failures from the outset

The indications for the operation and also the contraindications are described and evaluated

It is concluded that

1 In the rheumatoid knee anterior synovectomy is a pain relieving operation
2 The indications are wider than classically stated and can include knees with full thickness cartilage destruction and flexion deformities up to 20°
3 The majority of knees fail because of secondary degenerative change and this is manifested by pain rather than stiffness
4 Postoperative manipulation does not prejudice the final result
5 Associated popliteal cysts five in this series) can be cured by anterior synovectomy

Key words knee synovectomy results in advanced cases

Accepted 20 iii 76

This is an *independent* review by one of us (D.J.) of a series of anterior synovectomies of the knee done for rheumatoid disease in the Norwich area between 1964 and 1973 It is also an attempt to evaluate the clinical impressions which accumulated during the period under study

All of the operations were done by one surgeon (J G T.) or his trainees The indication was persistent pain and swelling in a rheumatoid knee Throughout the period under review it was the policy also to consider knees with relatively advanced disease for synovectomy The relative contraindications were

1) Flexion less than 90°
2) Instability
3) Varus or valgus deformity
4) Dry grating knee
5) Subchondral bone collapse on X ray

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Table 1 Clinical material

	Patients	Knees
Personally reviewed	36	43
Notes reviewed		
Dead	3	5
D N A	4	5
Untraceable	4	4
Total	47	57

Table 2 Cases personally reviewed

Follow up period	*16 months–10 years*
Patient ages	15 years–64 years
Males	14
Females	*22*

PATIENTS

All of the patients submitted to synovectomy were rheumatoid arthritics referred by the Department of Rheumatology (Table 1) This analysis however is of only those knees personally assessed amounting to 43 knees in 36 patients Details are shown in Table 2 At all stages in this investigation the notes and X rays of those seven patients who did not attend for review were studied to search for possible bias in the results of the personally reviewed series This is a non selected series Only two patients had monarticular disease A wide range of anti inflammatory drugs had been used during medical treatment Many patients had been submitted to temporary or long term steroid therapy

OPERATION

Subtotal synovectomy was done in most cases through a medial parapatellar incision In a minority via separate anteromedial and lateral incisions The suprapatellar pouch the medial and lateral recesses and the intercondylar notch were routinely cleared of synovium The menisci were removed only if they were severely degenerated The patella was excised if its articular cartilage was extensively destroyed but not for chondromalacia or isolated cartilage ulceration Postoperative management was standard Suction drainage was used for 48 hours The knee was immobilised in a plaster cylinder for 1 week The wound was then inspected and the knee mobilised If at least 60° of flexion had not been regained by the end of the third postoperative week then gentle manipulation was carried out The technique of manipulation was standard Under anaesthesia with thiopentone and scoline the knee was gently flexed to 90° It was then splinted in this position with an anterior plaster slab The following day the splint was removed and movements were recommended The knee was placed in the flexion splint at night until the physiotherapist was satisfied that flexion was not being lost

All wounds healed by first intention There were no serious postoperative complications. Histological evidence of active rheumatoid disease was obtained in all cases

RESULTS

The knees were graded as *successes* or *failures* at the time of review after a study of the notes and radiographs an interview with the patient, and a clinical examination A knee was judged to be a failure if it was the same as or worse than, preoperatively

Eleven out of the 43 knees in the personally reviewed series were graded as failures Inclusion of a review of the notes and radiographs of those seven patients (10 knees) who did not attend for assessment did not adversely alter this ratio (Table 3)

Up to the time of review only one patient from the personally reviewed series and the only known failure from the cases who did not attend for review had undergone further surgery In both these cases double osteotomy was done

Figure 1 shows the distribution of personally reviewed knees related to the duration of follow up at the time of review Approximately half these knees have been followed up for 4 years or less since half of all the failures became apparent more than 4 years postoperatively (Figure 2) it is expected that the up to 4 year follow up group will produce more failures

Table 3 All traceable cases

Patients	43
Knees	53
Failures	12 (23 %)
Further operations	2 (both double osteotomies)

Figure 1 Duration of follow up

In this series it has not been possible o obtain evidence that steroid therapy, seronegativity or positivity, or sedimentation rate, affects the result of synovectomy Also no valid conclusions can be drawn as to whether or not synovectomy affects the general arthritic process The prospective studies needed to obtain such information would be extremely difficult

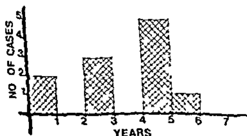


Figure 2 Period of time before failure became apparent in synovectomised knees Only two knees were failures from the outset

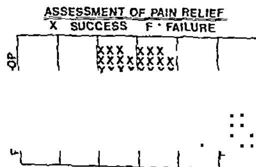


Figure 3 Assessment of pain relief

to carry out because of the many variables encountered

Pain relief

This is shown in detail in Figure 3 Pain has been graded 1-6 according to a d'Aubigne-Postel scale (d'Aubigne & Postel 1954) By this scale 6 equals no pain and 1 equals severe, spontaneous

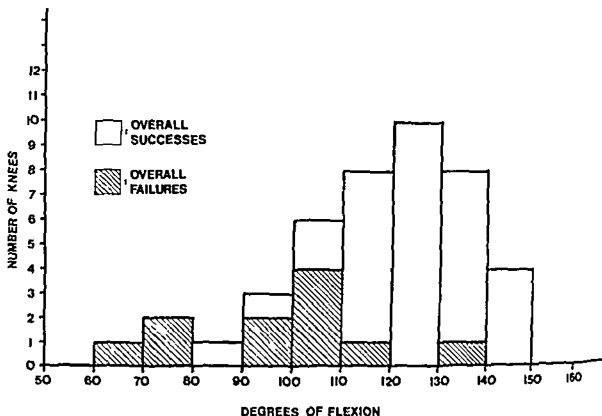


Figure 4 Knee flexion at the time of review At this stage only four knees had flexion less than 90°

pain Most of the successes were improved by two points on the scale Thirty-two of the 43 personally reviewed knees had complete or almost complete pain relief at the time of review One of these (F in column 6) had had a double osteotomy done and is therefore classified a failed synovectomy

Effect of synovectomy on knee flexion

The flexion of the knee related to success or failure at the time of review is shown in Figure 4 Only four knees out of 43 had flexion of less than 90° at the time of review In the successful group (32 knees), 20 knees had approximately the same flexion (± 10°) compared with that preoperatively, seven gained more than 10° of flexion and five lost between 10° and 20° of flexion These five are still graded as successes overall because of relief from pain and synovitis

Results in knees with more advanced changes

It has been the policy of this unit to consider knees with more advanced changes for synovectomy, and in fact almost half of the knees in this series are in this category Graduation of the severity of articular disease by X ray appearance has been avoided because the operative findings are frequently worse than the radiographic appearance would lead one to suspect The operation notes which for all cases in this series were in detail, were studied The presence of bare bone was used as the index of ad

Figure 5 a Case J I Bare bone at operation (1968) b Case J I The knee after synovectomy c Case J I Radiographs in 1968 and 1974 This knee lasted 5 years before it failed Over the past 2 years it has not deteriorated further The patient does not want further surgery because this is not at present her main disability


A
B
C



Figure 6 a Case 1 A Preoperative radiographs 1964 Bare bone present in all compartments Patellectomy done

vanced disease This means areas of full thickness cartilage destruction in weight-bearing areas of the joint The presence of peripheral erosions or osteophytes, or the degree of synovial proliferation are not considered as being necessarily indicative of advanced disease (Figures 5–7) Figure 8 shows the results Twenty knees had bare bone at the time of operation, and seven of these had a patellectomy as well as synovectomy The success/failure rate is the same as for the series as a whole The need to do a patellectomy did not seem to prejudice the result in the small number of cases in which it was done

Anterior synovectomy and popliteal cysts

Five patients in this series had popliteal cysts All these were cured by anterior synovectomy, thus agreeing with the findings of Pinder (1973)

Postoperative manipulation

Twenty-four knees were manipulated and 19 were not There was no significant difference between the manipulated and non-manipulated groups with regard to success or failure at the time of review

The cause of failure

The clinical signs and X-rays of the knees considered failures were analysed Findings suggest that the majority of knees fail because of secondary degenerative changes rather than recurrence of active synovitis (Table 4), and thus we agree with Marmor (1973) in this respect



Figure 6 b Case V A 1974 Still a clinical success Knee cool stable and painless Flexion 10°–130°

DISCUSSION

Most authors agree that knee synovectomy for rheumatoid disease is a valuable operation for relieving pain and improving functional capacity (Geens 1969) There is not however, complete general agreement on the indications, or, perhaps more importantly, on the contra indications for the operations For instance is the presence of a flexion deformity a contraindication to operation? Laurin (1971) and Laurin et al (1974)

Table 4 Analysis of clinical signs and X rays in failed cases to show that the cause of failure in the majority of cases is secondary degenerative change

Secondary degenerative changes	8
Synovitis	1
Mixed	2

state that it is, but in Marmor's series (1973) a flexion deformity up to 20° was considered acceptable We have not considered a flexion deformity a definite contraindication In fact, in the 43 personally reviewed knees in this series, 24 had flexion deformities of between 5° and 20° at the time of surgery Nine of these knees (38 per cent) were graded as failures This is a higher failure rate than for the series as a whole, but not high enough to make a flexion deformity up to 20° a contraindication

It has been frequently reported that knees which have clinically or radiologically advanced changes preoperatively do poorly following synovectomy (Geens 1969, Geens et al 1969, Graham & Checketts 1973, Laurin et al 1974) Lowry & Lele (1971) set out contraindications to synovectomy according to the

Figure 7 Case B.S. Operation 1963. Radiographs in 1969 and 1974; bare bone at operation. Still a success: painless, cool, stable, flexion 5°–125°. Note the radiological improvement.

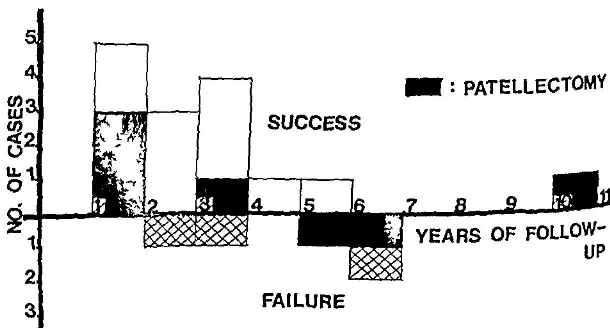


Figure 8 Fate of knees with bare bone. The failure rate is the same as for the series as a whole.

severity of the local disease, and define their grades of severity. However, in all series (Marmor 1973, Laurin et al 1974, Roles & Arden 1973), the fact remains that there are some knees with relatively advanced changes which have done well following synovectomy. Our small, but carefully documented and examined series shows that in the medium term, up to 5 years postoperatively, knees undergoing synovectomy in a more advanced stage of disease can do as well as those operated upon earlier. The necessity to do a patellectomy does not seem to influence the result.

With regard to the cause of failure in synovectomised knees, it has not been shown here that the majority of failures are due to a recurrence of synovitis, as reported by several authors (Ranawat et al 1971, Graham & Checketts 1973). Out of the eleven knees classified as failures in this series, eight were cool and dry and showed radiological degenerative changes, and two showed degenerative changes, but also had detectable synovial thickening and mild warmth; in only one case was there definite synovitis without radiological degenerative changes. It may well be that regenerated synovial membrane is grossly identical with the preoperative membrane (Patzakis et al 1973) but this does not necessarily imply that it is functionally or immunologically the same. If recurrent synovitis were the cause of the majority of failures, then we might expect resynovectomy to be a less rare operation than it is.

ACKNOWLEDGEMENTS

We wish to thank Drs Cardoe and Wenley for referring these patients to us and for their permission to review them. We would also like to thank Mr Burn and the Department of Medical Illustration United Norwich Hospitals, and our medical secretaries.

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Figure 7. Case B S Operation 1969. Radiographs in 1969 and 1974; bare bone at operation Still a success. Painless, cool, stable, flexion 5°–125°. Note the radiological improvement.

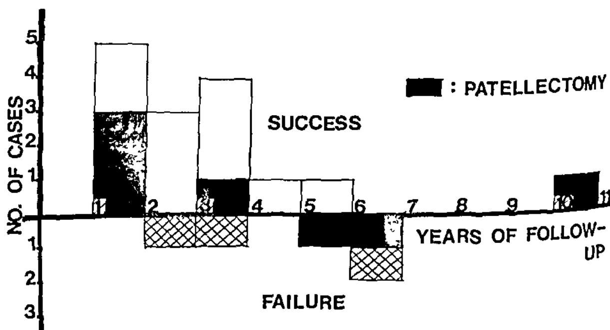


Figure 8 Fate of knees with bare bone The failure rate is the same as for the series as a whole

severity of the local disease, and define their grades of severity However, in all series (Marmor 1973, Laurin et al 1974, Roles & Arden 1973), the fact remains that there are some knees with relatively advanced changes which have done well following synovectomy Our small, but carefully documented and examined series shows that in the medium term, up to 5 years postoperatively, knees undergoing synovectomy in a more advanced stage of disease can do as well as those operated upon earlier The necessity to do a patellectomy does not seem to influence the result

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Acta orthop scand 47, 432-435, 1976

CRYPTOCOCCOSIS (TORULOSIS, EUROPEAN BLASTOMYCOSIS) OF THE KNEE JOINT

A Case Report with Review of the Literature

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A patient with monoarticular synovitis with an osteolytic lesion in the femoral condylar area due to *Cryptococcus neoformans* infection is presented. The role of exact diagnosis by synovial biopsy and fungal cultures in patients presenting with monoarticular synovitis is emphasized. The literature is reviewed. Drug therapy in conjunction with synovectomy is highly beneficial.

Key words: cryptococcosis, osteomyelitis, arthritis.

Accepted 18.ii.76.

Cryptococcal synovitis or arthritis is extremely uncommon. A case is presented and the literature is reviewed.

CASE REPORT

A 38-year-old black female, most recently employed as a factory worker and raised on a farm near Memphis, Tennessee (southern United States), was admitted to the University of Chicago Hospitals on November 16, 1972, with a 6-month history of pain in the right knee. Examination of the knee revealed effusion and and tenderness with restriction of flexion. X-rays of the knee at this time showed no osseous or articular abnormality. A knee aspirate showed a non-specific cytology.

Needle synovial biopsy done on November 24, 1972, showed acute and chronic synovitis with yeast-like organisms whose appearance was compatible with cryptococci. Cultures from this knee aspirate were positive for *Cryptococcus neoformans* and sensitive to Amphotericin B and Flucytosine (5-*Fluoro cytosine*).

Repeat X-rays of the knee joint on December 7, 1972, and subsequent laminograms on December 19, 1972, showed a lytic lesion in the intercondylar area anteriorly, about 1.5 cm in diameter (Figure 1 a, b). Skeletal survey showed this to be the only skeletal lesion.

Chemotherapy in the form of Amphotericin B and Flucytosine was instituted and a sub-total synovectomy followed by curettage and packing of the cavity with bone chips was carried out. The histopathological examination was consistent with the diagnosis of cryptococcal synovitis and osteomyelitis (Figures 2 and 3). Drug treatment was continued on February 15, 1973. By this time the knee had regained full range of motion and the patient was able to ambulate well with crutches. In August 1973 she developed discrete papular pruriginous lesions diffusely scattered over the body and histopathological examination revealed "sarcoid reaction" consistent with sarcoidosis.

The patient was last seen in June 1975. She was doing well, had a full range of motion and was free of effusion.

DISCUSSION

Despite the fact that *Cryptococcus neoformans* was first isolated in 1894 by San Felice from peach juice and the first case of osseous cryptococcosis along with



a) Laminogram of A P view (Defect could not be visualized in the routine A P view)



b) Lateral view

Figure 1 X rays of the knee showing an osteolytic area in the intercondylar juxtacortical portion of the joint

systemic involvement was reported by Busse & Buschke in 1894 (a truly isolated involvement of bone being reported by Brewer & Wood in 1908) not many cases of osseous cryptococcosis have been reported in the literature to date The now classic review of Collins in 1950 produced 17 cases with skeletal involvement out of 200 reported cases of cryptococci and to these 17 he added three of his own Fifteen cases had generalized cryptococcal disease while only five could be classified under the rubric of truly localized osseous involvement Lesions of bones joints and other somatic tissues are extremely uncommon in cryptococcosis (Cox & Tolhurst 1946) In 1970 Ong & Prathap found only 16 cases of osseous cryptococcosis in the remaining cases osseous involvement was part of a generalized cryptococcal disease Of the 16 patients listed nine had a solitary bone lesion Balsubramanium & Silva (1973) recently reported a case of spinal involvement in a 34 year old female

Any bone in the body may be involved

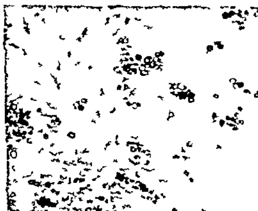


Figure 2 Gomori Methenamine silver stain of synovium showing numerous organisms in clusters

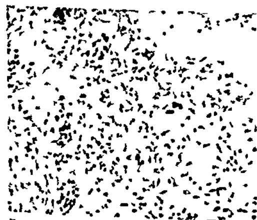


Figure 3 H & E stain of synovium showing granulomatous features and histiocytes containing groups of organisms

although the pelvis, vertebrae and skull are the most common sites (Ong & Prathap 1970) The infection is usually localized to the metaphysis of the involved bone (Collins 1950) Lesions, when multiple, are widely disseminated and tend to involve bony prominences They tend to be osteolytic, exerting very little bone reaction The X ray appearance is that of a discrete osteolytic lesion surrounded by a zone of dense bone Roentgenographically the bone lesions are indistinguishable from coccidioidomycosis The distinctive feature of cryptococcosis is the gelatinous or mucoid character of the pus formed On incising the abscess it gives the same impression as a myxomatous tumor

Osseous infection is an indirect one A constant source of virulent strains are pigeon droppings The infection usually is established in the lungs and other viscera before dissemination to the brain, meninges and bone Infection by direct inoculation has also been observed, e g, cryptococcal dactylitis immediately following a local injury to the finger (Littman & Zimmerman 1956)

An interesting association with other disease entities has been reported, especially with sarcoidosis where a dozen or so cases have been reported (Allcock 1961, Heller et al 1957, Kunity & Lewis 1968) and also with Hodgkin's disease (Collins et al 1951, Zimmerman & Rappaport 1954) The patient reported here is an example of an association with sarcoidosis Leopold (1953) presented a patient whose infection was associated with moniliasis

Cryptococcal synovitis is extremely rare In this patient the synovitis was the main feature Whether synovitis preceded the juxta articular lesion in the intercondylar area or vice versa is debatable The exact diagnosis in monoarticular arthritis is mandatory and fungal cultures should be a routine procedure especially when synovial fluid of an inflammatory nature is found Clinicians should be aware of the disease entity and the patient's possible exposure to the fungus is a point in favor With the increased mobility of a large portion of the population, exposure to *cryptococcus neoformans coccoides immitus* has become less limited to permanent residents of endemic areas

Skin testing, serological studies (latex agglutination test, tube agglutination test and indirect fluorescent antibody) and specific fungal cultures are important modes of laboratory investigations When synovial fluid cultures are negative, cultures of synovial tissue should be taken and here the role of needle biopsy is important The recent use of the Fibroptic knee arthroscope and the visualization of involved synovium for biopsy should lead to more positive results Successful synovectomy in coccidioidal synovitis has been reported (Greenman et al 1975, Pollock et al 1967, Sotele Ortiz 1955) Two out of four patients reported by Greenman et al had persistant synovial infection after a prolonged course of intravenously and intra articularly administered Amphotericin B and the active disease could be eradicated only after synovectomy Systemic therapy with Amphotericin B (and more recently 5-Fluoro-cytosine) should be used prior to synovectomy for surgical coverage in the hope of preventing dissemination during the operative procedure

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Coll ns V P Gellhorn A & Tr mble J R

synovial cells displaced into the meniscial tissues (Albert & Keller 1953)

METHODS AND RESULTS

The semilunar cartilages of the knee of six cases taken from the departmental files showing various degrees of mucoid cystic degenerative changes were reviewed The cystic spaces varied greatly in size and contained a mucoid gray white gelatinous material similar to the contents of ganglia with the slimy character and viscosity of synovial fluid Four of the cases involved the lateral meniscus and two the medial meniscus Three cases showed a distinct synovial like cell lining in some of the cystic spaces that contained mucoid material They were selected for electron microscopic study Only one of the three selected cases gave a history of trauma He was a 63 year old male with a cyst in the lateral meniscus of the left knee Clinically the patient suffered damage to both cartilages of the knee in an athletic injury more than 15 years previously He also gave a history of some buckling of his knee for many years He had had two unsuccessful surgical procedures (15 and 8 years previously for removal of meniscial cysts of the left lateral semilunar cartilage

At surgery there was a 5 cm large cystic mass involving the lateral meniscus On the cut surface it was made up of multiloculated cystic spaces containing gray white slimy mucoid material (Figure 1) The cysts measured from 0 6 to 3 0 cm in diameter The walls of the cysts were made up of a gray white firm tissue and averaged 0 3 cm in thickness

The meniscial cysts of the two remaining cases were multiloculated and smaller in size measuring up to 2 cm in diameter They were located in the lateral meniscus of the left knee The patients were both males 42 and 45 years old with no previous surgery or trauma and gave a history of buckling and swelling of the left knee for several years



Figure 1 Meniscial cyst filled with gelatinous material It measures 3 cm in diameter



Figure 2 Multiloculated cystic spaces (A B) filled with a mucinous alcian blue positive substance One of the cysts (A) is lined by synovial cells (arrow) (Hematoxylin eosin × 13)

Light microscopy

Blocks of tissue for light microscopy were fixed in 10 per cent formalin and stained with hematoxylin eosin alcian blue-PAS Gomori trichrome Mucicarmine and Gram Weigert staining for fibrin The sections revealed a fibrocartilaginous tissue with cystic spaces containing mucinous material *intermingled* in some areas with fragmented elongated dense masses of degenerative collagen The walls of the cysts were fibrous *with* occasional cysts showing flattened cell lining PAS alcian blue stain showed intraluminal masses of amorphous dense PAS positive material *representing* degenerated collagen tissue together with lakes of gelatinous alcian blue positive substance (acid mucopolysaccharides) (Figure 2) The Gram Weigert stain

Acta orthop scand 47, 436–440 1976

CYSTS OF THE SEMILUNAR CARTILAGE OF THE KNEE

A Light and Electron Microscopic Study

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The semilunar cartilages of the knee of six cases showing various degrees of mucoid degeneration with cyst formation were studied with the light microscope Three cases were selected for electron microscopic observation which revealed that some of the cystic spaces filled with mucoid material were lined by synovial cells Masses of mucinous, alcian blue positive material (acid mucopolysaccharides) were observed also among degenerated and intact bundles of collagen It is concluded that the accumulation of acid mucopolysaccharides in meniscal cysts is at least in part a product of secretion of synovial cells This observation explains the high incidence of recurrence of meniscial cysts after incomplete surgical excision and supports the concept that it is an active rather than a degenerative process

Key words semilunar cartilage, meniscus, meniscial cysts synovial cell displacement, acid mucopolysaccharides light and electron microscopic study

Accepted 21 iii 76

The cause of meniscial cysts is still being debated The history of trauma is unreliable and in most cases there is absence of a severe trauma so that a chronic, long standing minor trauma is regarded as significant in the development of meniscial cysts Patients are usually young adults, more frequently male than female, probably because the former are more often exposed to severe physical activity The lateral meniscus is more frequently affected than the medial meniscus An explanation for this is that the medial meniscus is firmly anchored and therefore more exposed to tears, while the lateral meniscus, because of its increased sliding and displacement range, is more protected against lacerations and has a tendency to show degenerative changes Increased pressure on standing over the lateral meniscus and variable degrees of congenital malformation of the joint surface of the external tibial condyle have been regarded as important contributory factors for the increased incidence of meniscial cysts in the lateral meniscus (Tkachenko & Yuriev 1972) There are two main hypotheses to explain the development of meniscial cysts While some authors regard the mucoid cystic regeneration of the ground substance with accumulation of acid mucopolysaccharides as the most important factor (Kulman & Szepesi 1970), others claim that the masses of acid mucopolysaccharides derive from the secretions of

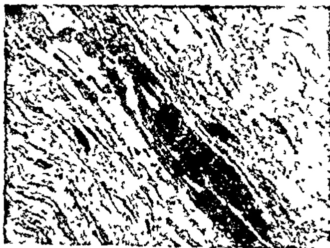


Figure 6 Globular amorphous osmiophilic fibrillary masses without cross striation which probably represent fibrin and degenerated collagen tissue (2 per cent uranyl nitrate and Reynold s lead citrate × 4 000)

showed dark bluish streaks in the cyst contents r presenting masses of fibrin Adjacent frozen secti ns which were submitted for immuno flu rescence studies showed fluorescent greenish el ngated masses in a similar location when treated with anti human fibrinogen rabbit anti bodies and fluorescein isothiocyanate attached t rabbit antiglobulins conjugate

Ele tr n microscopy

F r electron microscopy multiple small blocks f tis ue from different areas were fixed in 3 p r cent glutaraldehyde After postfixation with smium tetroxide the specimens were dehy drated and embedded in Araldite After trim ming the tissue secti ns were correlated by the adjacent thick thin section method 1 μ to 2 μ thick sections were made using a m crot me with a diamond knife They were stained with H&E alcian blue PAS and Gram Weigert stain Adjacent 60 70 mμ thin sections were stained with 2 per cent uranyl nitrate and Reynold s lead citrate sodium hydroxide solution Sections were examined with an electron microscope

Corresp nding to the alcian blue positive areas the adjacent thin sections showed con sistently am rph us homogenous masses of finely granular material in the lumen of the cystic spaces an l f etween bundles of intact and degenerate l c llagen The large cystic spaces were lined by syn vial cells characterized main ly by the presence of abundant m crovilli (Figure 3 Smaller cystic spaces showed an end th elial cell lining and were undoubtedly capillary vessels (Figure 4) The strongly PAS p sitive masses f degenerated collagen tissue c rresp nded in the electron microscope to bun lles f dense paque fibers without distinct periodicity (Figure 5) The streaks of dark blue areas in the Gram Weigert stain and the green ish fluorescent masses of fibrin material cor responded in the electron micrographs to amorphous globular fibrillary masses (Figure 6) Embedded in the fibrocollagenous matrix were fibroblasts and chondrocytes showing vari ous degrees of degenerative changes with dis ruption and fragmentation of the smooth and rough endoplasmic reticulum swelling of the mitochondria and intracytoplasmic vacuoliza tion Whorled and laminar intracytoplasmic in clusions were present in some of the cells

DISCUSSION

The origin of meniscial cysts is still in dispute The theories advanced to date are mainly based in histology findings Some authors consider chronic infection with hemorrhage as an initiating factor in the formation of the cysts (Jean 1924) Others regard meniscial cysts as the re sult of degenerative ch nges of collagen followed by necrosis of cells and accu mulations of acid mucopolysaccharides There are authors (Blanco et al 1953 and Ollerenshaw 1921) that postulate that meniscial cysts originate from congenital inclusion of synovial rests or from trau matic cleavages of the fibrocartilaginous tissue with subsequent penetration of synovial cells and joint fluid into the meniscus Other authors believe that the



Figure 3. Synovial cells with numerous elongated cytoplasmic processes with vacuoles lined the larger cystic spaces (2 per cent uranyl nitrate and Reynold's lead citrate × 10,300)

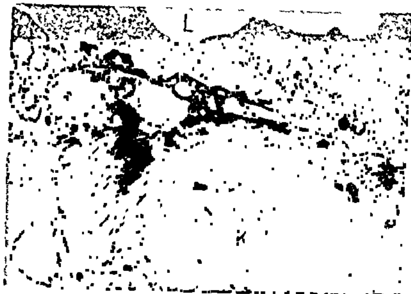


Figure 4 Granular amorphous masses of acid mucopolysaccharides were present in the lumen of the capillary vessels (L) (sectioning artifact) and between bundles of collagen fibers (K) The arrow points to the basement membrane of the capillary vessel (2 per cent uranyl nitrate and Reynold's lead citrate × 6,000)

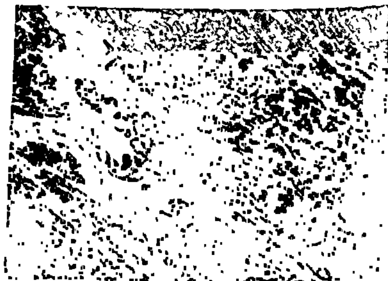


Figure 5 Degenerated bundles of collagen They were found inside some of the cystic spaces as amorphous strongly PAS positive masses together with lakes of mucin (2 per cent nitrate and Reynold's lead citrate × 4,000)

cta orthop scand 47, 441–447, 1976

PATELLECTOMY AFTER FRACTURE

Long-term Follow-up Results with Special Reference to Functional Disability

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Twenty-eight out of a group of 38 patients, who had undergone a patellectomy during the period 1950–70 were investigated clinically and radiologically The results were compared with the subjective symptoms of the patients to see if there was a correlation The follow up period was 7 4 years on average A good subjective result was reported by only six patients The predominant subjective symptoms were weakness of the limb and pain on movement and/or exertion The most usual findings were atrophy of the quadriceps muscle, crepitation and palpation tenderness The muscular power of the quadriceps was found to be greater than or equal to 75 per cent of the power of the intact knee in only seven cases (25 per cent)

Key words patella, fracture, muscular power, quadriceps muscle, physiotherapy

Accepted 20 iii 76

The effect of patellectomy on the function of the knee is a matter of controversy Brooke s (1937) excellent functional re sults (supported by Hey Groves 1937) were quite soon challenged by experimental and/or clinical studies by Bruce & Walmsley (1942), Haxton (1945), and later by O Donoghue et al (1952), De Palma & Flynn (1958), and recently by Kaufer (1971) Their studies showed that patellectomy diminished the extension power of the knee and caused various postpatellectomy symptoms in a con siderable number of the patients

With this information in mind, we thought it worthwhile to conduct a post-examination of a material with a long follow up period, in which in the majority of cases a patellectomy had been performed as an emergency operation following fracture Special attention was paid to postpatellectomy symptoms due to the procedure, as well as to an analysis of their causes

MATERIAL AND METHODS

During the period 1950–1970 patellectomy was performed on 38 fracture patients at the Department of Surgery, Turku University Central Hospital The follow up examination of the 28 patients included a clinical evaluation of subjective symptoms and objective findings The extension power of the knee was measured using a dynamometer, and a roentgenological study was performed In 18 cases the primary X ray pictures were available The results were compared with the subjective symptoms described by the patients to check for correlation The operation had in most cases been performed as an emergency (Table 1) The right patella was

meniscial cysts represent ganglia that originated as a result of a degenerative process and that the accumulation of acid mucopolysaccharides represents secretory activity of certain connective tissue cells (King 1940) or synovial cells displaced into the fibrocartilaginous tissue (Albert & Keller 1953) The electron microscopic findings in the cases reported here showed evidence of synovial cells lining some of the cysts that contained collections of acid mucopolysaccharides and, therefore, suggested that the accumulation of this substance was the result of secretory activity of the synovial cells in a similar way to synovial fluid The findings described support the view that meniscial cysts are comparable with ganglion cysts and that the development of meniscial cysts is the result of displacement of synovial cells into the fibrocartilaginous tissue However, other findings such as the accumulation of acid mucopolysaccharides between intact and degenerated fibrocollagenous fibers without morphologic relationship to synovial cells favor the theory that regards the formation of meniscial cysts as a degenerative process with necrosis of collagen fibers, fibroblasts and chondrocytes and the subsequent accumulation of a large amount of acid mucopolysaccharides that lead to cyst formation Therefore, two main factors play an important role in the development of meniscial cysts one is trauma followed by tears or microscopic cleavages through which synovial fluid and synovial cells are pressed into the fibrocartilaginous tissue where they proliferate, secrete large amounts of acid mucopolysaccharides and form cystic spaces, and the other is the degeneration of the collagen tissue with secondary accumulation of masses of acid mucopolysaccharides

ACKNOWLEDGMENTS

This study was supported by the Park Ridge United Fund, Park Ridge Illinois

The surgery was performed by R Lidge MD and Miss Teresa Valdivieso (MT) assisted in the preparation of the electron micrographs

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Table 2 Follow-up examination of 28 patellectomy cases comparing the patient's assessment of the knee with the extension power on the basis of measurement

Patient's assessment of the knee	Groups* according to the extension power of the knee A	B	C	D	Total
Good	5		1		6
Fair	2	7	6	3	18
Poor		1	2	1	4
Total	7	8	9	4	28

* See the text Follow up

knee was taken to be the measure of the extension power of the knee

Since the subjective symptoms seemed to correlate with the extension power of the musculus quadriceps an analysis was made to check this possible correlation after dividing the cases into four groups according to the extension power Group A power greater than or equal to 75 per cent group B power 50 to 74 per cent group C power 25 to 49 per cent and group D power less than 25 per cent in all cases referring to a percentage of the extension power of the intact knee (Table 2) Both knees were X rayed

RESULTS

Subjective symptoms The subjective result was reported as good by 6 patients (22 per cent), fair by 18 and poor by 4 patients (Table 2) Weakness was the subjective symptom most often reported, whereas pain after exertion and during movement occurred in nearly half of the material (Figure 2) None of the patients belonging to group A complained of having ache (pain at rest), and five out of seven patients in group A described the condition of the knee as good

Objective findings In only 7 out of 28 patients was the power greater than or equal to 75 per cent of the power of the intact knee (Table 2) On average, the extension power of the patellectomized knee had decreased significantly, being only 54 per cent (at 90°) and 53 per cent (in full extension) of the extension power of the intact knee (Table 3) Troublesome subjective symptoms occurred in the groups with the least power (groups B, C and D Figure 2) Of the four pa

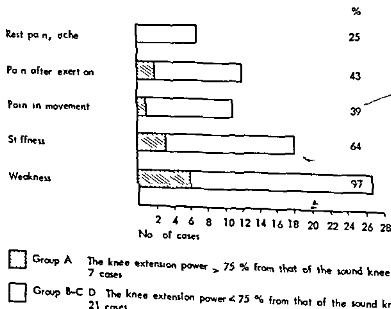


Figure 2 Subjective symptoms in 28 followed up cases of total patellectomy Cases belonging to group A are shown in the hatched parts of the columns

Table 1 Timing and indications for operations in 38 cases of total patellectomy

Time elapsed since injury	No of cases	Indication
Emergency–2nd day	34	35 comminuted fractures, among which were 2 open fractures 1 transverse with gross chondral damage, 1 refracture after cerclage osteosynthesis
3rd–12th day	3	
At 8 weeks	1	Infection after cerclage osteosynthesis

fractured in 24 cases and the left in 14 Ten patients had multiple injuries Three patients had fractures of the same extremity as that with the fracture of the patella One had a leg prosthesis on the same side and one had severe rheumatoid arthritis

Sex and age Seventy one per cent of the patients were men The average age was 47 years the average age of the men was 42 and that of the women 60 years The average age of patients involved in traffic accidents was 40 years, whereas for the others it was 54 years

There were almost three times the number of the cases in the latter 11 years (1960–1970) as there were in the first half of the period (Figure 1) Traffic accidents predominanted as the cause of fracture

Operation technique The operation was performed with a transverse incision After the removal of fragments, the aponeurosis was sutured with silk or synthetic material in 22 cases, with chromic gut in 14 and with wire in 2 cases Special attention was paid to the reconstruction of the lateral expansions of the aponeurosis

Postoperative immobilization lasted 4 weeks (from 2 to 6 weeks) on average Quadriceps training was started immediately It was not possible (especially in the beginning of the period under study, to give every patient postoperative physical therapy under the supervision of a physiotherapist

Postoperative complications There was one superficial infection and one thrombophlebitis in the material, neither of which involved any residual symptoms The choice of the suture material did not affect the stability of the tendon repair Two patients with open fractures recovered without infection occurring

In the mathematical calculation of the numerical values of the extension power of the knee Student s *t* test was used

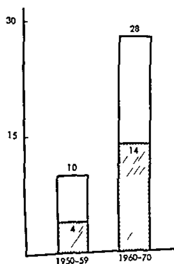


Figure 1 Patellectomy 38 cases The hatched part of the column shows the proportion of fractures caused by traffic accidents in the material

Follow up

The follow up period varied from 1 to 19 years, the average being 7 4 years The follow up examination is based on the results of 28 patients Six of the patients had died during the follow up period and four were not available

As regards subjective symptoms the patient expressed his own view about the general condition of the knee (good fair, poor, Table 2) and gave details of the extent of disability (Figure 2)

In the clinical study (Figure 3) the local status and function were recorded (range of movement use of stairs especially descending stairs etc) The power of musculus quadriceps was measured in kiloponds using a dynamometer according to the principle presented by Duthie & Hutchinson (1958) The extension power was measured both at an angle of 90° and in full extension Each measurement was under taken three times and the highest value was noted The average of the two values (at the 90° angle and the 180° angle) as a percentage of the corresponding numerical value of the intact

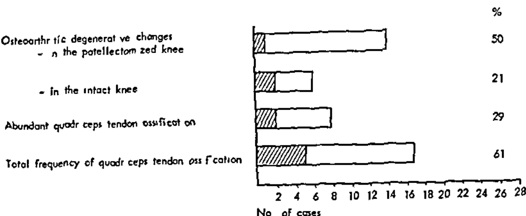


Figure 4 X ray findings in 28 cases of total patellectomy Cases belonging to group A are shown in the hatched parts of the columns

months (2 6 months on average) There were no significant differences between the various groups

Roentgenological findings (Figure 4) Osteoarthritic changes were observed in the injured knee in 50 per cent of the total material On the other hand it was possible to observe the occurrence of degenerative condylar changes in only 4 out of 18 cases for which roentgenograms taken immediately after the trauma were available In one of these four cases the changes had increased and in the other three patients they had appeared during the observation period (at 1 4 and 10 years) The osteoarthritic changes also showed a tendency to be associated with a decreased function of the musculus quadriceps because they mostly occurred in the groups with a diminished extension power (groups B C and D)

Ossifications in the quadriceps tendon were present in more than half of the material They were abundant in eight cases (Figure 5) in two cases belonging to group A Thus a large calcification in the quadriceps tendon was not a hindrance in achieving a good extension power

The duration of observation did not seem to have any significance as regards the distribution of cases into the various groups (A D)

DISCUSSION

According to our results postoperative symptoms appear quite frequently Good subjective results were only obtained in 20 per cent and good objective results in 54 per cent of the cases (groups A and B), and the results could thus be regarded as inferior to those presented in some previous reports excellent or good results in 83 per cent (Khong & Pillay 1967) in 75 per cent (Duthie & Hutchinson 1958), in 67 per cent (West 1962), and in 69 per cent (Mishra 1972) On the other hand Nummi (1971) stated that the result was good in 36 per cent and Bostrom (1972) found good results in only one out of five cases During the follow up examination of the material it appeared that the extension power of the quadriceps was the most reliable single factor in assessing the results of the patellectomy

Subjective and objective weakness as well as atrophy of the quadriceps muscle associated with weakness were very common postpatellectomy findings in our material This was also reported by West (1962) and Duthie & Hutchinson (1958)

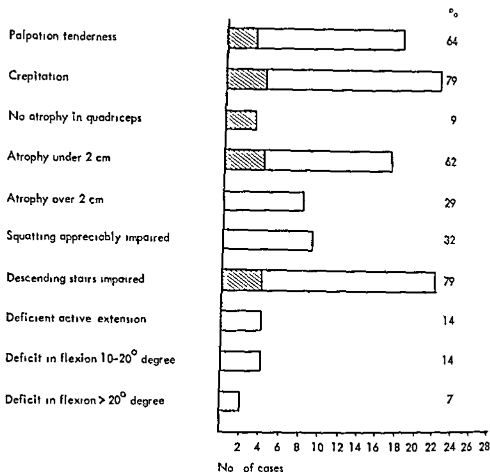


Figure 3 Objective findings in 28 followed up cases of total patellectomy Cases belonging to group A are shown in the hatched parts of the columns

tients in the weakest group (group D), one was 79 years old, another had totally neglected the postoperative treatment and training, the third had severe rheumatoid arthritis, and the fourth was the only case with a late patellectomy (after an infected osteosynthesis) The result was regarded by the authors as good in groups A and B, i e, in 15 patients (54 per cent) As additional objective findings (Figure 3) impaired ability to descend stairs and muscular atrophy were observed in the majority of the cases Atrophy of more than 2 cm was found in groups B, C and D (in 8 out of a total of 21 cases) but not in group A The occurrence of flexion and extension limitation was slight

The period of time off work because of the patellar fracture varied from 1 to 6

Table 3 Extension in kiloponds of the operated and intact knee Mean and SEM values of 28 followed up cases are given

Position of the knee	Extension power (kp SEM) Patellectomized knee (n = 28)	Intact knee (n = 28)	Decrease of power as a percentage of the value of the intact knee
90°	7 9 ± 0 93	14 5 ± 1 10	54
180°	5 0 ± 0 62	9 4 ± 0 86	53

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Figure 5 Abundant calcifications in the quadriceps tendon of a patient belonging to group A

Apparently a good extension power is the major criterion even in the patient s own assessment of the condition of his knee (five good patients out of seven belonged to group A) The impairing effect of a concomitant condition on the result of the operation (four patients in group C) must be considered when setting operative indications There were some areas in which the results were better in our material than in previous materials e g ache and pain during movement (cf Scott 1949) limitation of flexion (cf West 1962) and ossification of the quadriceps tendon diminishing the extension power (cf Friberg 1941 Duthie & Huthinson 1958) On the other hand the incidence of secondary osteoarthrosis in our material was a little more than that reported by Jani (1966)

The importance of performing a patellectomy as soon as possible after trauma has been emphasized by O Donoghue (1958) Khong & Pillay (1967) and Jani (1969) According to the cadaver experiments made by Haxton (1945) and recently by Kaufer (1971) the contribution of the patella to knee extension increases with progressive extension A diminished power (moment arm) in the extension of the knee caused by the lack of the patella is evidenced by the fact that postpatellectomy extension may require as much as a 30 per cent increase in the necessary quadriceps power as shown by Kaufer (1971) Thus if some time has elapsed between the trauma and the patellectomy e g in unsuccessful osteosynthetic measures the starting point for the patellectomy has already received a decisive set back because of quadriceps atrophy and insufficiency A long period of time (up to 1 year) needed for a full recovery (Duthie & Hutchinson 1958) places rehabilitation in an extremely important position in the treatment of patellectomized patients Starting physical therapy immediately after the operation is imperative according to the study mentioned above and an immobilization period of about 3 weeks should be sufficient Numerous subjective postpatellectomy symptoms and negative objective findings could obviously be diminished by an intensive strengthening of the quadriceps muscle

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Acta orthop scand 47, 448–453, 1976

FRACTURES OF THE TIBIA IN CHILDREN

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A total of 102 children, aged 1–15 years, treated for fissures, infractions and fractures of the tibia were studied to elucidate the influence of age, type of fracture, and mechanism of trauma upon the course of union. In addition, an assessment was made of the possibilities the child has of correcting deformities of the diaphysis during continued growth. Eighty-five of the children were followed up clinically and radiologically. The time taken for union to occur increased with increasing age. The "high energy" injuries were found to be more apt to cause transverse and comminuted fractures, with injury to the skin than the "low energy" fractures. At the time of union 25 patients had angular deformities. The mean correction of this deformity up to the time of follow up was only 10 per cent. The tendency to correct the deformity ceased 18 months after the accident, and was independent of the child's age at the time of the accident.

Key words: tibia, fractures, children, conservative treatment, spontaneous correction of angular deformities

Accepted 22.iii.76

During the period March 1971 to January 1972 a total of 102 children were admitted to the Gentofte Hospital for the treatment of fissures, infractions, or fractures of the tibia. The material does not include injuries involving either the proximal or distal tibial epiphysis. Figure 1 gives the age distribution and the sex ratio.

According to the radiographic appearances the fractures were divided into (1) fissures and infractions, (2) oblique fractures, and (3) transverse and comminuted fractures. Incomplete fracture lines were classified as fissures. Infractions are injuries with displacement, but without a breach of continuity in the entire circumference. In an oblique fracture the length of the fracture line is more than twice the width of the bone. In a transverse fracture the length of the fracture line is less than twice the width of the bone. Double fractures and other multi-fragmented fractures were classified as comminuted.

As stated by Adams (1964) the nature of the trauma is assumed to be reflected in the type of fracture, direct trauma being associated with transverse fractures and indirect trauma with oblique fractures. According to Bauer et al. (1962) the traumas can be divided into those caused by severe and those caused by moderate violence. The former com-

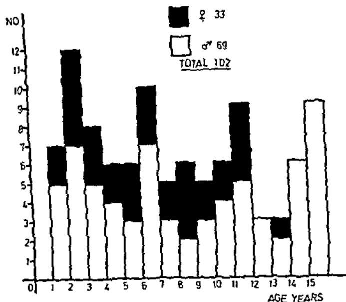


Figure 1 Age distribution and sex ratio. White columns represent number of boys within each age group. Black columns the number of girls

HEALINGTIME WEEKS

F = FISSURES AND INFRACTIONS
L = OBLIQUE FRACTURES
T = TRANSVERSE AND COMMINUTED FRACTURES

AGE IN YEARS

Figure 2 Mean times of union for each age group within the three types of fracture

prise injuries in which a motor vehicle has been involved, or the patient has been hit by a heavy object, or has fallen from a height of more than 3 metres. Moderate violence is taken to mean a fall at ground level or from a low level (chair, bed, or the like), sport accidents, run into by bicycles etc. Table 1 lists the distribution of the fractures by type and mechanism of trauma.

TREATMENT

All the patients were treated conservatively in plaster casts, 62 without reduction, 33 after reduction, 4 after two or more reductions. Three fractures had initially been treated abroad and there was no information as to whether or not they had been reduced. One patient was briefly treated with calcaneal traction prior to the application of plaster.

Table 1. Distribution of the fractures according to type and mechanism of injury. The relation between fracture types and trauma is shown without distinguishing between boys and girls. Out of 33 patients exposed to severe violence 22 sustained transverse or comminuted fractures and 9 out of the 14 compound fractures were in this group. Out of 67 patients exposed to moderate violence 49 sustained fissures, infractions or oblique fractures.

TYPE / AETIOLOGY	FISSURES AND INFRACTIONS	OBLIQUE FRACTURES	TRANSVERSE AND COMMINUTED FRACTURES	TOTAL
SEVERE VIOLENCE	6	5 / 1	22 / 8	33 / 9
MODERATE VIOLENCE	26 / 1	23 / 2	18 / 2	67 / 5
NO INFORMATION	1	1		2
TOTAL	33 / 1	29 / 3	40 / 10	102 / 14


FRACTURES WITH AND WITHOUT SKIN INJURIES


FRACTURES WITH SKIN INJURIES

The time of union was assessed on the basis of clinical and radiological findings. In the present retrospective study the time of union was assumed to coincide with the time of removal of the plaster cast, which ranged from 2 to 18 weeks after the accident. The times of established union for each type of fracture distributed according to age, are shown in Figure 2.

A stepwise multiple regression analysis was carried out on the times of union for each type of fracture. For fissures and infractions the union time in weeks was: age × 0.24 + 3.8 (with residual standard deviation = 1.7). For oblique fractures the time of union in weeks was: age × 0.48 + 4.8 (with residual standard deviation = 2.2). Lastly, for transverse and comminuted fractures in weeks: age × 0.51 + 4.8 (with residual standard deviation = 2.8). In other words there is a very limited possibility of fixing the times of union on the basis of age and type of fracture.

Complications

The following complications were recorded. One patient had impaired sensibility in the foot, one had a peroneus palsy, one developed infection at the site of skeletal traction and one developed a cutaneous necrosis on the heel. All these complications were transient and left no permanent damage.

FOLLOW-UP

Of the 102 patients, 85 (83 per cent), 56 boys and 29 girls, were followed up clinically and radiologically. All the follow-up examinations were performed by the authors. Seventeen patients were not included in the follow-up examinations: three because of deficient radiographic material, two because of continued treatment in other hospitals and two because of previous fractures of the same or the contralateral limb. The remaining ten patients failed to respond to the invitation to attend follow-up.

The distribution by fracture type in the follow-up material is shown in Table 2.

The follow-up period averaged 24.2 months, range 13–36 months.

Subjective assessment. In six cases the children and/or parents reported pain after major exertion, there was no cor-

Table 2 Distribution of fracture types in the follow-up material

Types of fracture	No of pts
Fissures and infractions	28
Oblique fractures	24
Transverse and comminuted fractures	33
Total	85

relation between the subjective assessment and the clinical/radiological findings

Objective assessment There were no patients with a limp or abnormal toe off in walking In all cases there was a symmetrical movement in the hip, knee, and ankle joints In two instances there was restriction of subtalar mobility of one-third and two-thirds that in the contra lateral subtalar joint

Rotational deformity was assessed only clinically This was found in five patients and was between 10° and 20°

At the radiographic examination, spot orthoradiography was done on all 85 patients

The material was analysed with a view to spontaneous correction of angular deformities at the fracture site during the period between union and follow-up. In measuring the angular deformity we measured the angle between the axes of the diaphyseal fragments proximally and distally to the fracture site without regard to apposition and resorption at this level The degrees stated are the sum of the angulation in the anteroposterior and lateral views The measurements are illustrated in Figure 3 b

At the completion of treatment 25 patients had angular deformities between 4 and 19° The same 25 patients still had major or minor angular deformity at follow up, range 3° 19° At the time of union the angular deformity among the 25 patients was found to total 252°, at follow up 218° Thus, the spontaneous correction had been 252 217 ≈ 34°, viz

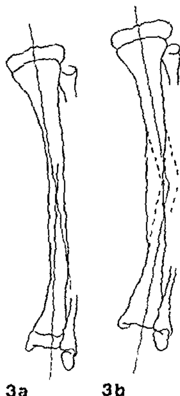


Figure 3 Measurement of angular deformity (a) Angular deformity measured as the angle of intersection between a line placed through the centre of the bone ends and the centre of the diaphysis (b) Angular deformity measured as the angle of intersection between the prolonged axes of the proximal and distal fragments (method used in the present study)

a correction of 13 5 per cent Figure 4 gives the correction for the individual age groups, Figure 5 that in relation to the length of follow-up period

The correction during the follow-up period was not correlated with the angular deformity at the time of union

DISCUSSION

Treatment of fractures of the lower leg in children is considered to be gratifying, as they have, as stated by Blount (1955), a short time of healing, a low complication rate, and no cases of delayed union or non-union, if surgery is omitted

prise injuries in which a motor vehicle has been involved, or the patient has been hit by a heavy object, or has fallen from a height of more than 3 metres Moderate violence is taken to mean a fall at ground level or from a low level (chair, bed, or the like), sport accidents, run into by bicycles etc Table 1 lists the distribution of the fractures by type and mechanism of trauma

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A stepwise multiple regression analysis was carried out on the times of union for each type of fracture For fissures and infractions the union time in weeks was age × 0 24 + 3 8 (with residual standard deviation = 1 7) For oblique fractures the time of union in weeks was age × 0 48 + 4 8 (with residual standard deviation = 2 2) Lastly, for transverse and comminuted fractures in weeks age × 0 51 + 4 8 (with residual standard deviation = 2 8) In other words there is a very limited possibility of fixing the times of union on the basis of age and type of fracture

Complications

The following complications were recorded One patient had impaired sensibility in the foot one had a peroneus palsy one developed infection at the site of skeletal traction and one developed a cutaneous necrosis on the heel All these complications were transient and left no permanent damage

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The distribution by fracture type in the follow-up material is shown in Table 2

The follow-up period averaged 24 2 months, range 13–36 months

Subjective assessment In six cases the children and/or parents reported pain after major exertion, there was no cor-

Fourteen compound fractures, 10 of which were in the group 'trauma resulting from severe violence', posed no special problems, the union time within this group being within that expected for the corresponding age groups with closed fractures

As may be seen from Figure 2, the times of union for fissures and infractions within the individual age groups are somewhat shorter than those for oblique and transverse fractures In contrast there is no difference in the times of union for transverse and comminuted fractures on the one hand and oblique fractures on the other As demonstrated by the regression analysis the time of union increases with increasing age for all types of fracture

In 25 patients the examination on completion of treatment showed angular deformity At follow up there was still marked angular deformity, viz 86 5 per cent of that measured at the time of union The mean deformity at the time of union was about 10° for each age group The correction proved to be independent of the extent of deformity at the time of union From Figure 4 it is apparent that unlike Swann & Oppers (1971) and Moesner et al (1966), we did not find decreasing correction of the angular deformity with increasing age

As shown in Figure 5, we observed some correlation between correction of angular deformity and follow up period in all 25 patients with deformity (Spearman rank test $R_s = 0\ 45$ $N = 25$ $P < 0\ 01$) However, analysis of the 16 patients followed for more than 18 months (Spearman rank test $R_s = 0\ 22$ $N = 16$) no longer showed a correlation between correction and follow up period ($P > 0\ 1$)

The difference between the findings of previous authors and the findings in this study is presumably due to the measuring method outlined in Figure 3, which does not take into consideration apposition or resorption at the fracture site This apposition and resorption must be assumed to influence the static condition at the fracture level, but remodelling at the fracture site alone does not alter the static condition in the knee joint and ankle joint Thus, if the deformity is not corrected in the epiphyseal plates the weightbearing on the adjacent joints will remain faulty

In conclusion, prognosis of plaster treated fissures, infractions, and fractures of the tibia is favourable in children up to fifteen years of age Primary union may be expected in all cases regardless of the type of fracture, whether the fracture is compound or closed, and whether the mechanism of the injury is a high or low energy force Complications are few and transient

A correct axial reduction has to be performed, as a correction of the angular deformity of more than about 10 per cent of the original deformity cannot be expected irrespective of the child's age at the time of fracture

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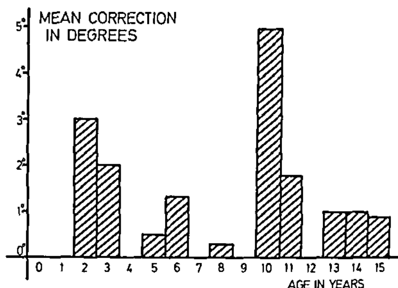


Figure 4 Correction of angular deformity in the individual age groups On the ordinate the mean correction in degrees on the abscissa age A Spearman rank test ($R_s = -0\ 08$, N = 25) showed no significant correlation between correction and age ($P > 0\ 5$)

In the present material there were no cases of delayed union or non-union in the 99 patients whose treatment was completed in our department Complications were transient At follow-up six patients reported pain after major exertion

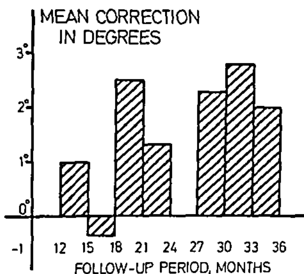


Figure 5 Influence of follow up period on correction of angular deformity Ordinate Mean correction of angular deformity in degrees Abscissa Follow up period in months A Spearman rank test ($R_s = 0\ 45$ N = 25) showed a significant correlation ($P < 0\ 01$) between correction and follow up period

In two of these cases this could possibly be explained by the severity of anisomelia and angular deformity present

At the clinical examination it was difficult to assess the rotational deformity A deformity of between 10° and 20° was recorded in five patients, but in two of these the injury was merely a fissure, so that the measurement must be assumed to be incorrect It is unsatisfactory not to have a practically applicable method for assessing rotational deformity In particular, it would be of interest to check this displacement after the primary reduction, as it is generally considered the only deformity which children do not spontaneously correct (Blount 1955)

From the literature Edwards (1965) collected large series of lower leg fractures in adults Out of 1558 conservatively treated cases of closed fractures three, or 0 2 per cent, developed osteomyelitis Out of 723 cases of compound fractures he found 107 cases (15 per cent) of osteomyelitis Moreover, he found the time of union for compound, transverse fractures to be up to four times that of closed oblique fractures In our material primary union occurred in all 99 children

Fourteen compound fractures, 10 of which were in the group 'trauma resulting from severe violence', posed no special problems the union time within this group being within that expected for the corresponding age groups with closed fractures

As may be seen from Figure 2, the times of union for fissures and infractions within the individual age groups are somewhat shorter than those for oblique and transverse fractures In contrast there is no difference in the times of union for transverse and comminuted fractures on the one hand and oblique fractures on the other As demonstrated by the regression analysis, the time of union increases with increasing age for all types of fracture

In 25 patients the examination on completion of treatment showed angular deformity At follow up there was still marked angular deformity, viz 86 5 per cent of that measured at the time of union The mean deformity at the time of union was about 10° for each age group The correction proved to be independent of the extent of deformity at the time of union From Figure 4 it is apparent that unlike Swann & Oppers (1971) and Moesner et al (1966), we did not find decreasing correction of the angular deformity with increasing age

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In conclusion, prognosis of plaster treated fissures, infractions, and fractures of the tibia is favourable in children up to fifteen years of age Primary union may be expected in all cases regardless of the type of fracture whether the fracture is compound or closed, and whether the mechanism of the injury is a high or low energy force Complications are few and transient

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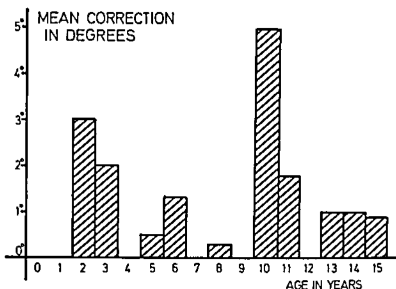


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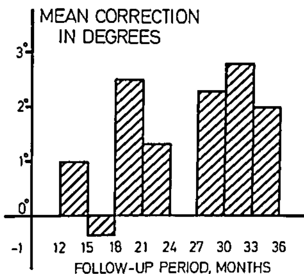


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Acta orthop scand 47, 454–458, 1976

CONSERVATIVE TREATMENT OF ACHILLES TENDON RUPTURE

A Follow-up Study of 14 Cases

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A follow-up study of 14 patients with *Achilles tendon rupture is reported* The patients were treated by conservative methods i e with immobilization in a plaster cast for 8 weeks with the foot in the relaxed equinus position Solid healing of the tendon was obtained in *13 cases As assessed by* the patients, the end result was unsatisfactory in two, fairly satisfactory in one and fully satisfactory in 11 cases

Key words Achilles tendon rupture, conservative treatment

Accepted 2 ii 76

For many years, surgical repair has been the treatment used in Achilles tendon rupture Complications such as wound infection, skin necrosis, suture loosening, sural nerve injury and tendinocutaneous adhesion have been tolerated because a ruptured Achilles tendon, like other tendon lesions, readily lends itself to surgical intervention

Conservative treatment has been reported in a few cases, for example, by Arner & Lindholm (1959), but a large series in which this mode of treatment was systematically applied did not appear until 1972 (Lea & Smith)

METHODS

The diagnosis of subcutaneous total Achilles tendon rupture is established on the basis of the history and clinical picture—preferably supplemented by soft part radiography in order to ensure a greater diagnostic certainty

Conservative treatment using the method of Lea & Smith (1972) consists of immobilization in a plaster cast applied from the toes to below the knee with the foot in the relaxed equinus position—usually about 30° A walking iron is incorporated in the cast, and the patient is allowed to bear full weight as soon as the cast is dry, with a compensatory elevation on the unaffected side The cast is removed after 8 weeks and the patient is instructed to use a 2.5 cm homolateral heel lift and to undertake active exercises of the muscles and joints It is of the greatest importance that the plaster cast is retained for 8 weeks, and that a heel lift is used after its removal

RESULTS

During the period from March 1973 to April 1975 a total of 15 patients with Achilles tendon rupture were admitted to our department Of these, 14 were treated conservatively, while one refused this form of treatment Those who underwent conservative treatment were subjected to a clinical follow-up examination in May 1975, and the end results were further checked by answers to a standard questionnaire in December 1975



Figure 1 Below knee plaster cast with incorporated walking iron and the foot in relaxed equinus position

The results appear in Tables 1 and 2 Immobilization had been performed within the first 3 days after the rupture except in cases 9 and 14, in which 8 days and 6 weeks, respectively, had elapsed

It can be seen that complications developed in four patients In case 2, re rupture occurred 11 days after the removal of the cast, but further immobilization for another 8 weeks led to a per fect result In case 12, re-rupture occurred 7 days after the removal of the cast, but was not recognized until 2 months later No further treatment was carried out because the functional result was good, and the patient was satisfied with the condition In case 9, there was a tendency to oedema, but the tendon was solidly healed In case 3, instability of the ankle joint developed, necessitating surgical correction of an elongated ten don The operation, performed in a spe cialized orthopaedic hospital, showed a solidly healed tendon with abundant amounts of fibrous tissue, the tendon was shortened by a tenoplasty

The clinical follow up examination re vealed normal gait without pain in 11 pa

Table 1 Age distribution and course of treatment

Case no	Age at time of rupture	Observation period (months)	Duration of hospital treatment (weeks both in and out patients)	Complications
1	23	26	12	0
2	24	14	23	Re rupture
3	25	20	14	Elongation of tendon tenoplasty
4	25	11	11	0
5	26	11	10	0
6	39	23	10	0
7	41	10	12	0
8	44	21	10	0
9	47	33	13	Deep thrombophlebitis
10	47	13	17	0
11	57	21	14	0
12	64	23	12	Re rupture—no treatment
13	70	29	11	0
14	71	30	10	0
Average	43	21	12	

Tal le 2 Clinical observations at the follow up exa nu al on

Passive dorsiflexion of ankle joint	No of cases	Maximal calf circ mference	No ca es
Unchanged	8	Unchanged	3
Increased (10 degrees)	5	Decreased (0 5 2 0 cm)	10
Decreased (10 degrees)	1	Increased (1 0 cm)	1



I gure 2 a Case 1 one year after Ach lles ten lon rupture Full we gl tbear ng o tl e ball of tl e affecte l left foot Note th cl en ng of the ten lo

tients cases 9 and 12 had a slight limp but no pain Case 3 could not be assessed because of the short postoperative period and later on for geographical reasons

No attempts were made to measure the muscular power of the affected leg but 13 of the patients could bear full weight on the ball of the affected foot There was no tenderness at the site of rupture but some thickening was present in all cases

The end results as reflected by answers to the questionnaire appear Table 3 Many of the patients were ach sportsmen and we have tried to assess tl influence of the treatment on their sporting activities in Table 4

DISCUSSION

The complications encountered in o conservatively treated patients were s i



I g re 2 b Sa ne pat et t as in F gure 2 a—normal r ght foot

Table 3 End results according to answers to questionnaire

	No of cases
Walking capacity after treatment	
Unchanged	12
Reduced less than 25 per cent	1
Reduced by 25 50 per cent	1
Subjective discomforts	
None	10
Slight stiffness of ankle joint	1
Tendency to oedema limping diminished power of leg	3
Patients own assessment of end result	
Fully satisfactory	11
Fairly satisfactory	1
Unsatisfactory	2 *

* Cases 3 and 9

ilar to those described by other authors Thus, *Lea & Smith (1972)* reported re-rupture in seven out of 55 cases, including four which healed after a second period in plaster, and their end results were satisfactory in 52 cases Nistor (1974) experienced one re rupture among 12 patients this, too, healed after conservative treatment Gillies & Chalmers (1970) had one re rupture in seven patients

In their follow up study of 86 patients treated with surgical repair, Arner & Lindholm (1959) encountered deep thrombophlebitis in two patients, with fatal pulmonary embolism in one of them, necrosis of the skin over the Achilles tendon in 11 cases, wound infection in three, suture loosening in 10, including four with refractory fistula formation, re rupture occurred in four cases In a group of 37 patients, Kristensen & Andersen (1970) saw wound infection in six, suture loosening in one, and re-rupture in one

Re rupture is a complication which may occur both after surgical and conservative methods, but it is apparently more frequent after the latter form of treatment Anyway, it seems as if repeated conservative treatment does not affect the end result (Lea & Smith 1972, our case 2)

As regards re rupture, it is, in our view, very important that the patients are informed of this risk, and that they use the heel lift

Late sequelae seen in our series were calf atrophy, thickening of the tendon at the site of rupture and impaired mobility of the ankle joint Similar sequelae after surgical repair were reported by Arner & Lindholm (1959) and Kristensen & Andersen (1970) and seemed to occur with equal frequency after both modes of treatment From a functional point of view, the two methods appear to give equally good end results

As long as further research has not proved which of the two is the better principle, conservative treatment may be used as an alternative in cases in which surgical repair should be avoided

Table 4 Sporting activities according to answers to questionnaire

Case no	Type of sport	Activity level after treatment	Difference in power between the legs
1	Football + cross-country	Unchanged	None
2	Badminton	Dissuaded for one year	None
3	Gymnastics	Stopped	Great
4	Badminton	Unchanged	None
5	Badminton	Diminished	None
7	Football + badminton	Unchaoged	None
9	Football + football referee	Diminished	Moderate
10	Gymnastics	Diminished	None

Table 2 Clinical observations at the follow up examination

Passive dorsiflexion of ankle joint	No of cases	Maximal calf circumference	No
Unchanged	8	Unchanged	3
Increased (10 degrees)	5	Decreased (0 5 2 0 cm)	10
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Figure 2 b Same patient as in Figure 2 a—normal r ght foot

Acta orthop scand 47, 459–462, 1976

CONSERVATIVE TREATMENT OF FRESH SUBCUTANEOUS RUPTURE OF THE ACHILLES TENDON

LARS NISTOR

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Twelve patients with rupture of the Achilles tendon were successfully treated with immobilization in plaster for 8 weeks and with raised shoe heels for 4 weeks The results are discussed in the light of earlier literature on surgical versus conservative treatment

Key words achilles tendon, athletic injuries, tendon injuries

Accepted 2 ii 76

After having danced a whole night in 1766 John Hunter sustained a rupture of the Achilles tendon, which he himself successfully treated with bandaging (Dobson 1969) In 1929, however, Quenu & Stoianovitch found that the results of published cases were often poor when the rupture had been treated conservatively, but good when treated surgically The finding was corroborated by Christensen (1953) and Arner & Lindholm (1959), after which it was generally accepted that treatment of the condition should be surgical This opinion was, however, seriously questioned after Lea & Smith's publication (1972) of 66 cases treated conservatively

To assess the value of such conservative treatment, from January 1973, all cases seen at the Department of Surgery, Central Hospital, Halmstad were treated conservatively

MATERIAL AND METHODS

Twelve men aged between 30 and 53, with rupture of the Achilles tendon sought medical advice within 24 hours of the injury In nine of the men the rupture occurred during the performance of athletics and in three it occurred at work Eleven patients had a subcutaneous rupture with a typical history of acute, intense heel pain followed by inability to raise the heel when standing They reported severe dorsiflexion of the foot when the ball of the foot was loaded In one patient the tendon was severed by metal shavings on the workshop floor

The diagnosis was based on palpation of a defect of the tendon and positive "calf squeeze test" (Hierton 1960, Thompson & Doherty 1962)

The patients were treated in accordance with the method of Lea & Smith (1972) with the foot in 'gravity equinus position", first with the lower leg in plaster with a heel and afterwards with raising of the shoe heels by 2 5 cm It was often necessary to change the plaster after 2–3 weeks because it broke or became too large The plaster cast was maintained for 7 weeks in four of the patients and for 8 weeks in seven patients After removal of the plaster the patients used shoes with a high heel for about 4 weeks and were instructed to exercise the foot without resistance They were allowed to resume their athletic activities 4–6 months after the accident

In one of the patients the tendon ruptured again Three days after his first plaster had been removed he bent his knees and while in the squatting position he extended the healthy leg and loaded the affected leg in maximal dorsiflexion with the entire weight of the body At his own request he was treated for a further

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'satisfactory results" in nine out of 16 patients who had received only expectant treatment Of Arner & Lindholm s (1959) six unoperated patients, two had been treated with plaster for 2 and 5 weeks, respectively, and four with only an elastic bandage In only one case was the result satisfactory So it would seem that in earlier papers rejecting conservative treatment, the cases referred to had been immobilized inadequately or not at all It was therefore considered justifiable to reconsider conservative treatment

It has been shown in experimental animals that the Achilles tendon can heal even if part of it is resected (Conway et al 1967, Lipscomb & Wakim 1961) That the Achilles tendon can heal even after division was shown by Boyd et al (1949) in a study of intermittent claudication Savill (1960) described a case of necrosis of the skin and tendon which healed with the foot fixed in lower leg plaster for 10 weeks He said "It seems to indicate that satisfactory recovery can be expected without operation if the foot is immobilized in full equinus for 8 weeks after the acute injury

Recent investigations (Gillies & Chalmers 1970 Lea & Smith 1968, 1972) have corroborated this assumption and have shown that adequate conservative treatment of rupture of the Achilles tendon can produce good results comparable to those obtainable by surgery The results achieved in the present investigation lend further support to this impression

Owing to the relatively insignificant though demonstrable reduction in strength after recovery, Moberg (personal communication) feels that one should consider operation on patients such as elite athletes who place very high demands on their muscles and joints Gillies & Chalmers (1970), who compared the results of surgical and conservative treatment found no difference in reduction of strength between the two groups Their relative loss of strength was the same as that noted in the present investigation

The disadvantage of conservative treatment is the frequency of re rupture (Sadow 1973, Inglis 1973 Forste et al 1974) Re rupture occurred in one of Gillies & Chalmers (1970) six cases, in seven of Lea & Smith's (1972) 66 cases, in four of Inglis' (1973) 50 cases, and in one out of 12 cases in the present series This means an overall percentage of somewhat less than 10 per cent In the operated series, Christensen (1953) reported re rupture in only two cases (6 per cent) and Arner & Lindholm (1959) in four (4 per cent)

The frequency of re-rupture must, however, be considered in relation to per- and postoperative complications Arner & Lindholm (1959) reported a case in which the patient died from pulmonary embolism during the postoperative period But wound infection, skin necrosis and fistula formation must also be regarded as major complications Minor

Table 2 Complications of operative treatment of Achilles tendon ruptures Major complications Death wound infection skin necrosis tendon necrosis fistula formation Minor complications Scar fixation disturbance of sensibility ugly scars

Author	No of cases	Major compl	Minor compl
Arner & Lindholm (1959)	86	19	39
Gillespie & George (1869)	46	–	16
Gillies & Chalmers (1970)	6	1	–
Goldman et al (1969)	33	4	1
Hooker (1963)	28	5	4
Lawrence et al (1955)	23	3	1
Savill (1960)	33	6	–
Schönbauer (1964)	240	77	–
Viernstein & Galli (1964)	154	11	7
	649	126	68

Table 1 Results of follow-up after conservative treatment of Achilles tendon ruptures In patient 1 the tendon was severed Patient 2 was troubled by thickening of the tendon Patient 4 had a re rupture and reported morning stiffness

Patient	Age	Follow-up (months)	Range of motion (°) increase +, decrease — Plantar	Dorsal	Calf circumference (cm) injured/noninjured	Power in plantar flexion, per cent of that on non injured side
1	32	19	0	+5	40/40	100
2	40	18	—10	0	38/40	95
3	45	18	0	0	34/35	85
4	39	14	0	0	32/34	90
5	38	15	— 5	0	39/40	95
6	43	11	0	0	34/34	95
7	49	10	0	0	35/34	100
8	53	9	—10	—5	36/37	80
9	47	9	0	0	38/39	75
10	30	6	0	0	37/38	100
11	39	5	0	+5	37/38	90
12	30	5	— 5	+5	38/39	75

8 weeks in plaster and was afterwards mobilized in the way described above without any complications

RESULTS

All 12 patients were reviewed by the author 5 19 months after the injury

One patient was troubled by thickening of the tendon and one by morning stiffness, but all 12 were satisfied with the results and all denied any consequent impairment of their athletic performance or their working ability

The mobility of the injured foot was compared with that of the unaffected one and was found to be slightly limited in four of the patients, but none of them were aware of the difference In most of the patients the circumference of the calf was 1–2 cm smaller on the affected side But the decrease was not correlated with the gross functional strength of the calf muscles The strength of the gastrocnemius muscles was assessed from the ability of the patient to stand tip-toe on one leg—which all could—and more objectively with the aid of an apparatus resembling that used by Gillies & Chalmers (1970) in their investigation of rupture of the Achilles tendon Measured with this apparatus, the strength of the injured side was 70–100 per cent of that on the other side The increase in breadth was found to be 0 5–1 0 cm, compared with the uninjured side In the two patients examined 5 months after the injury the tendon was 1 5 cm broader The results are summarized in Table 1

DISCUSSION

Several authors have found surgical treatment of rupture of the Achilles tendon to produce good results (Quénu & Stoianovitch 1929, Christensen 1953, Lawrence et al 1955, Arner & Lindholm 1959, Savill 1960, Hooker 1963, Schonbauer 1964, Viernstein & Galli 1964, Gillespie & George 1969, Goldman et al 1969 and others), but only three of them have discussed cases treated conservatively

Quénu & Stoianovitch (1929) traced several literature cases that had been treated by bandaging or rest for a varying period Of 15 patients in whom the results were known, six made a good recovery Christensen (1953) reported

Acta orthop scand 47 463-468 1976

DECOMPRESSION WITH THE AID OF INSOLES IN THE TREATMENT OF DIABETIC NEUROPATHIC ULCERS

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Thirty seven out of 38 neuropathic ulcers in 21 diabetic patients healed during relief of external pressure obtained by properly fitted interchangeable insoles The time required for healing was 1 to 12 months (mean 3 6 months) The presence of mild occlusive arterial disease did not influence the course of healing Gross infection which occurred in eight patients could be controlled by immobilization antibiotics and in the presence of pus by radical surgical drainage

Key words diabetes foot wear insoles neuropathic ulcers skin perfusion pressure strain gauge plethysmography

Accepted 22 iii 76

The term *neuropathic ulcer* is used for the special type of lesion that may occur in a neuropathic foot regardless of the cause e g *diabetes mellitus tabes* syringomyelia hereditary sensory radicular syndrome or leprosy Other terms employed are malum perforans *perforating* ulcer of the foot trophic ulcer and plantar ulcer The lesion is caused by impaired sensory perception either peripheral or central in origin in combination with increased mechanical stress on a limited skin surface The patient has no warning mechanism and is unaware of where and how he places his foot and he does not perceive trauma As the patient is usually able to walk without any handicap the lesion shows very little tendency to spontaneous healing

The vast majority of neuropathic ulcers in our patients are found in diabetic patients The ulcer is typically found on the feet where the normal architecture is lost e g under a prominent metatarsal head (Figure 1) or on the pulp or the tip of a rigid toe Penetration to tendons and bones is not uncommon A callosity surrounds the lesion indicating the increased mechanical stress

Decompression of the ulcers can be achieved by carefully manufactured insoles In most cases this therapy is effective as will be described in the present study

MATERIAL AND METHODS

Patients

In a 3 year period (1 10 1971 to 31 8 1974) 38 neuropathic ulcers in 21 diabetic patients were treated. The series is consecutive including diabetic patients with a pain free ulcer in a

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Chiropodist

complications such as scar fixation, disturbances of sensibility and ugly scars are rarely mentioned in the discussion of the results, but are nevertheless important in the comparison of surgical and conservative treatment Those authors who have included postoperative complications in their publications have most often reported major complications in 10–20 per cent of their cases and minor complications in 10 per cent (Table 2)

It is perhaps possible to reduce the frequency of postoperative complications, but it may also be equally possible to reduce the frequency of re-rupture after conservative treatment This might perhaps be achieved by placing the foot in equinus position with the leg raised early in the treatment to reduce the haematoma in the rupture It is also possible that the immobilization in plaster should be prolonged or that more effective measures should be taken to prevent involuntary dorsiflexion after removal of plaster since it is then that the re rupture is apt to occur

The results of conservative treatment are comparable to those obtainable by surgery Conservative treatment of subcutaneous rupture of the Achilles tendon is an easily justifiable method of treatment despite the relatively high frequency of re-rupture

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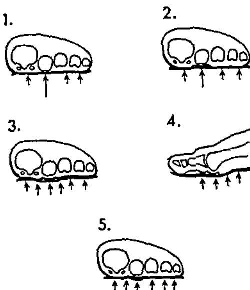


Figure 3 Protrusion of a metatarsal head (1) causing ulceration in the neuropathic foot (2) The insole has an excavation large enough to relieve pressure from the ulcer including the callous rim (3) Distally the edge of the excava tion is levelled (4) Prophylaxis is achieved by a suitable small excavation after healing of the ulcer (5)

ual excavation (Figure 3 (5)) In our hospital if no complications occur, the ulcers are treated by chiropodists who trim the callosities and manu facture and adjust the insoles*

The arterial condition of the limbs was determined by measurement of the distal *systolic blood pressure* on the ankle and on the first toe (or second toe) by strain gauge technique (Gundersen 1972 Nielsen et al 1972) The distal *perfusion pressure* was measured on the dorsal side of the foot by isotope technique or on the heel by photoelectric technique (Holstein & Lassen 1973 Holstein et al 1976) According to the criteria given by Nielsen & Munkgaard Rasmussen (1973) 10 patients had normal distal blood pressures i e no arterial occlusions, and 11 patients suffered from occlusive arterial disease of varying degree Six of these patients had intermittent claudication Severe occlusive arterial disease suggestive of ischemia as a cause of slow healing ulcers was excluded by accepting only ulcers in limbs where all distal blood pressures were above 40 mmHg (Lassen & Holstein 1974)



Figure 4 Partial washable insole

The severity of the neuropathy was determined by clinical examination with the exception of the vibration sense which was measured by biothesiometry (Steiness 1957) Table 2 shows the neurological findings

Table 2 Evidence of neuropathy

		No of patients
Reflexes		
Knee and ankle reflexes present		1
Knee reflex present ankle reflex absent		5
Knee reflex absent, ankle reflex absent		15
Sensation in the toes		
Intact		3
Vibration sense	absent	12
	decreased	6
Position sense	absent	2
Perception of pinprick	absent	13
	decreased	5
Perception of temperature	absent	9
	decreased	9
Perception of light touch	absent	2
	decreased	5

* The above principles have been taught at the school for chiropodists in Copenhagen since 1969



Figure 1 Neuropathic ulcer



Figure 2 Distribution of 38 neuropathic ulcers

skin area exposed to abnormally high external pressure as evidenced by a callosity and in whom severe occlusive arterial disease could be excluded

The localization of the ulcers is shown in Figure 2 and the duration before therapy in Table 1 The series includes four relapses of a healed ulcer and six new ulcers i e ulcers with a new localization which occurred in the follow-up period of 3 to 35 months (mean 16 3 months) Ten patients were men and 11 were women Their ages ranged from 48 to 74 years (mean 59 9 years) Diabetes of more than 10 years duration was noted in 11 patients and diabetes of 5–10 years duration in five patients Ten patients required insulin and in 11 patients the diabetes was controlled by diet and peroral hypoglucaemics The blood sugar in most patients was satisfactorily controlled

Method

Basically the external pressure to the ulcer is simply reduced by distributing the pressure to a greater skin area in most cases to areas proximal and bilateral to the ulcer This is obtained by an interchangeable insole in which a flat excavation corresponding to the size of the ulcer is created The insole is made of light thermoplastic, washable materials (Plastozote® Rubazote® Hindafoam®) It is important that the excavation in the insole is slightly greater in size than the ulcer, so that the callous rim is also relieved from pressure (Figure 3 (3)) Distally, the edge of the excavation is levelled or removed (Figure 3 (4) and Figure 4) This arrangement allows healing of the ulceration without restricting the walking activity of the patient The size of the excavation in the insole is diminished during the course of healing and new insoles are required from time to time

Partial insoles are often used initially (Figure 4) especially in the case of major discharge from the ulcer Then the excavation must be large enough for a dressing which should be arranged without wrinkles (ETE® compress) In narrow deep ulcers a slim wick is placed for drainage Tight plugging of the ulcer must be avoided Later a complete insole is manufactured preferably after imprints in a plastozote model sole on which the patient has walked for a week or two [illegible] per [illegible] by [illegible]

Table 1 Duration of the ulcers

1– 7 years	3
3–12 months	5
1– 3 months	3
< 1 month	20
Unknown	7

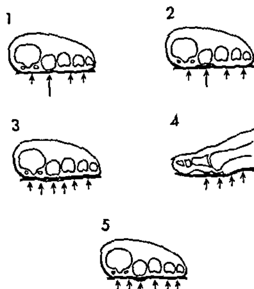


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Figure 4 Partial washable insole

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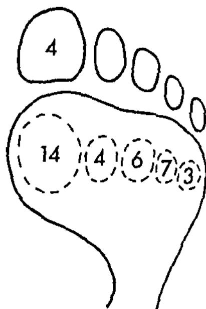


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Table 1 Duration of the ulcers

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Unknown	7

the shoes during walking were reported by Barrett & Mooney (1973) who demonstrated high frictional forces at the ulcer shoe interface The in shoe testing also demonstrated an abnormal pressure distribution on the forefoot as compared to barefoot walking

In our series there was a relative high frequency of ulcers localized under the first metatarsal head as was also found by Kelly & Coventry (1958) The lateral shift of the maximum load as demonstrated by Stokes et al (1975) is one interesting factor probably related to motor neuropathy But the site of the ulcer (or the callosities) is probably determined by a series of factors including also the individual abnormalities of the architecture of the foot the pattern of the gait and the type of foot wear

The neurological state of diabetics with neuropathic ulcers was recently studied by Barrett & Mooney (1973) The area immediately around the ulcers was painless but this sensory disturbance did not imply the whole distribution of a particular peripheral nerve The authors suggested that local damage to the small sensory nerve endings was an important factor in the absence of pains In our series there were three patients with intact sensation of the toes and feet in spite of a pain free ulcer of typical localization and appearance This supports the theory of local nerve damage In this instance it is notable that the mechanical factor in these three patients was extreme one patient had bilateral pes cavus and the two other patients were obese

The mechanical factor is the one which may be eliminated Good results have been achieved by surgical decompression (Martin 1954 Oakley et al 1956 Kelly & Coventry 1958 McCook et al 1966 Catterall 1968 Ellenberg 1968) It is often pointed out that surgical therapy was undertaken when conservative measures of relieving pressure such as bed rest use of walking casts and proper shoes had failed However surgical therapy such as ray resection is in principle unattractive as it reduces the weightbearing area possibly exposing new skin areas to intolerable external pressure This has been demonstrated objectively by Stokes et al (1975)

The interchangeable insole is an alternative method of eliminating the mechanical factor Frequent adjustments of the insoles according to the imprints corresponding to the heavily loaded areas make possible a proper pressure distribution and after healing of the wound prophylaxis is established

The four relapses in this series occurred after the patients had omitted to use their insoles We have occasionally seen ulcers appearing after the patients had been provided with individual hand made shoes for foot deformities and in the literature warnings against rigid shoe wear with relief pads as conventionally used for metatarsalgia are found (Oakley et al 1956 Barrett & Mooney 1973) For these reasons any patient susceptible to neuropathic ulcers should benefit from individual insoles which would also be a valuable and easily adjustable supplement to hand made shoes

ACKNOWLEDGEMENTS

This study was supported in part by grants from "Hjerteforeningen" and from "Den Lægevidenskabelige forskningsfond for Storkobenhavn og Færoerne og Gronland"

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RESULTS

In only one case was healing of the ulcer *not obtained* The ulcer, 16 mm in diameter, was localized under the first metatarsal head and had persisted for 7 years when the treatment was initiated Three years later the patient died At this time the ulcer was 5 mm in diameter No local complications of the ulcer occurred during the period of treatment and the patient had no sign of occlusive arterial disease The other 37 ulcers healed in an average of 3 6 months (range 1–12 months) The time required for healing of the ulcers could not be related to the duration of the diabetes or the severity of the neuropathy Nor did the presence of mild occlusive arterial disease influence the healing time which was 3 6 months (range 1–11 months) against 3 5 months (range 1–12 months) in diabetics without occlusive arterial disease

Eight patients had deep infection as a complication to the ulcer when first admitted to the hospital In five patients the infection was cured by high doses of appropriate antibiotics given systematically In three patients the deep infection resulted in osteitis Long-term antibiotic treatment cured one case In two other cases control of the infections was achieved by local but radical surgical drainage combined with long-term antibiotic treatment

The four relapsed ulcers healed after the treatment was recommenced, and the six ulcers occurring at new sites healed after suitable adjustment of the insoles

DISCUSSION

Lesions on the feet in diabetic patients were classified by *Oakley* (1954) as neuropathic, septic, ischaemic or due to a combination of these causes This classification gives the key to the proper therapy and should replace the non-specific term "diabetic gangrene" which is still commonly used

The importance of an *objective* determination of the arterial supply should be emphasized Ischaemia of the toes may be present even when the pedal pulses can be felt (Holstein & Sager 1973) and only methods that evaluate the most peripheral part of the circulation suffice, as was also recently pointed out by Faris (1975) *Vice versa* the blood supply may be adequate for the healing of wounds in spite of absent peripheral pulses The results in this series demonstrate that mild occlusive arterial disease does not affect the healing of the ulcers

In the case of deep infection, possibly with extensive necrosis of soft tissues the clinical assessment of the distal circulation is especially difficult We consider deep infection in a diabetic foot as an emergency case Immobilization and proper antibiotics given in the early phase may be adequate, but the patient often comes late because pains are moderate or lacking Then in the presence of pus radical surgical drainage is mandatory and if the blood supply is not too inadequate most limbs can be saved In severe occlusive arterial disease, diabetic foot lesions seldom show the clear cut *characteristics* of the chronic neuropathic ulcer and ischaemia is the factor which determines the localization, appearance and prognosis

It is generally accepted that the two important factors in the pathogenesis of the neuropathic ulcer are the increased mechanical stress and the sensory neuropathy Stokes et al (1975) measured quantitatively the load distribution under the feet of diabetic patients walking *barefoot* on a load sensitive area All patients with ulcers exerted maximum loads at the site of the ulcer Diabetics without ulcers, as compared to normal subjects, had alterations in loading which showed as a lateral shift of the highest maximum load on the forefoot and a decrease of the load carried by the toes Semiquantitative measurements *inside*

Acta orthop scand 47, 469–471, 1976

BONE MINERAL LOSSES IN ALCOHOLICS

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Bone mineral measurements were performed at five skeletal sites in seven alcoholics The mean annual loss of bone mineral in alcoholics was about 2 per cent higher than that of controls

Key words osteoporosis, bone mineral, alcoholics, photon attenuation measurement

Accepted 29 iv 76

Alcoholics have a high incidence of fractures (Nilsson 1970) This fact may be explained by an increased exposure to trauma It is also possible that the increased incidence of fractures in alcoholics is caused by bone fragility since they have a reduced bone mass as compared with controls (Saville 1965, Nilsson & Westlin 1973, Dalen & Feldreich 1974)

The purpose of the investigation presented here was to study quantitatively the bone mineral losses in different parts of the skeleton in a number of alcoholics

MATERIAL AND METHODS

The change in bone mineral content was determined by X ray spectrophotometry (Jacobson 1964 Gustafsson et al 1974 Dalén & Jacobson 1974) By this method the amount of bone mineral in the radiation beam is measured per unit area (mg mm²) By scanning over a site of the skeleton a profile of the mineral content is obtained and the mineral content per unit length of the bone (mg mm) is automatically calculated Soft tissue absorption is compensated for by using two radiation energies

Measurements were made at five sites: distal radius and ulna femoral neck, femoral shaft and calcaneus (Dalen & Jacobson 1974) The follow up time was 43 0 months (S D = 1 9) for the alcoholics and 43 1 months (S D = 1 5) for the controls

The investigation was conducted on seven patients at the Alcoholic Research Clinic, Karolinska Sjukhuset, Stockholm, and on seven age-matched controls The patient selection was limited to middle age subjects in whom the period of excessive alcohol consumption varied from 7–40 years The patients were included in a group described earlier by Dalen & Feldreich (1974) They were not socially deprived and none had undergone gastric resection The mean age for the alcoholics at the end of the follow-up time was 55 9 years (S D = 4 2) and for the controls 56 3 years (S D = 4 1)

RESULTS

The bone mineral content in the alcoholics and the controls at the end of the investigation is given in Table 1. At all five skeletal sites the bone mineral content in the alcoholics was decreased as compared with the controls (Table 2)

DISCUSSION

Alcoholics were found to lose bone mineral and the result is in accordance with

systolic blood pressure in the extremities Thesis *Acta chir scand*, Suppl 426
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Table 1 Bone mineral content in alcoholics and controls at the end of the investigation The deviation in the alcoholics is expressed as a percentage of the mean value for the controls

	Controls (mg/mm)		Alcoholics (mg/mm)		Deviation per cent	t value	P
	Mean	S D	Mean	S D			
Radius + ulna, distal	185	39	171	38	− 7 7	0 7	> 0 05
Radius + ulna, shaft	246	34	233	25	− 5 2	0 8	> 0 05
Femur, neck	348	51	336	17	− 3 6	0 6	> 0 05
Femur, shaft	594	42	547	32	− 8 0	2 4	< 0 05
Calcaneus	323	49	239	45	− 25 9	3 3	< 0 05

previous observations (Saville 1965, Nilsson & Westlin 1973, Dalen & Feldreich 1974) The loss of bone mineral was of the same magnitude as in postmenopausal women (Dalen & Lamke, to be published) Since the fracture incidence is greatly increased after menopause (Alffram & Bauer 1962) it appears reasonable to assume that the bone mineral losses found will lead to a weakening of the skeleton

Table 2 Annual loss of bone mineral in alcoholics as compared with controls

	Percentage loss	t value	P
Radius + ulna distal	0 2	0 1	> 0 05
Radius + ulna shaft	− 2 5	2 0	> 0 05
Femur neck	− 0 7	0 5	> 0 05
Femur, shaft	− 2 1	1 7	> 0 05
Calcaneus	− 3 4	3 4	< 0 05
Mean of sites	− 2 3	2 5	< 0 05

The effect of alcohol on the skeleton has been experimentally studied by Saville & Lieber (1965) Ethanol-fed rats were found to have a low bone density as compared with that of controls The difference in bone density could be explained by difference in weight Ethanol was therefore interpreted to have an unspecific effect on the skeleton acting as an inhibiting factor on growth

Little is known of the mechanism in man A relationship between bone mass and variables such as physical activity (Dalén & Feldreich 1974) and nutrition (Lowe & Labbate 1970) has been found in alcoholics Other possible factors are endocrine imbalance and impairment of the D-vitamin metabolism due to liver cirrhosis Many alcoholics develop peptic ulcers and have undergone gastric resection which will contribute to bone mineral losses (Nilsson & Westlin 1972)

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Acta orthop scand 47 473–479 1976

EXPERIMENTAL STUDIES ON CONNECTIVE TISSUE OF THE CAPSULAR LIGAMENT

Influences of Aging and Sex Hormones

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Influences of aging and sex hormones on connective tissue metabolism in the hip joint capsule of Wistar rats were analyzed both biochemically and morphologically As age advanced collagen content and collagen fibril diameter of the hip joint capsule tended to increase gradually in both sexes until sexual maturation was reached Collagen content was significantly greater in males than in females after sexual maturation The collagen content and fibril diameter were considerably increased by ovariectomy and significantly decreased by the administration of estrogen or estrogen combined with progesterone whereas they were significantly increased by the administration of testosterone in orchiectomized male rats

Key words hip joint capsule aging sex hormones collagen content collagen fibril diameter

Accepted 12 vii 76

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The aim of the present experiment is to study the influences of sex hormones on collagen metabolism in the joint capsule by analyzing the collagen content and collagen fibril diameter This analysis is an approach to clarifying the causative factors of the relaxation

MATERIALS AND METHODS

Treatment of animals

Fifty two Wistar rats 26 females and 26 males 3 30 weeks of age were subjected to an analysis of the influences of aging and 180 Wistar rats 105 females and 75 males were subjected to an analysis of the influences of sex hormones

The rats were kept in individual cages and fed on Nihon CLEA Rat Chow and given water *ad libitum*. They underwent ovariectomy orchiectomy or sham operation at 3 weeks of age with or without subsequent hormone treatment

The hormones administered to each animal group were estradiol benzoate (20 µg per rat) progesterone (10 mg per rat) and testosterone propionate (2 5 mg per rat) dissolved in 0 1 ml of sesame oil Control groups received sesame oil only The injections were given twice a week subcutaneously

At 10 weeks of age the animals were first stunned with a blow and then killed by cervical dislocation The joint capsules of the hip and knee were dissected free of fatty tissue the right capsules were prepared for electron microscopic examination and the left ones were hydrolyzed and assayed for hydroxyproline

Acta orthop scand 47 473 479 1976

EXPERIMENTAL STUDIES ON CONNECTIVE TISSUE OF THE CAPSULAR LIGAMENT

Influences of Aging and Sex Hormones

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At 10 weeks of age the animals were first stunned with a blow and then killed by cervical dislocation The joint capsules of the hip and knee were dissected free of fatty tissue the right capsules were prepared for electron microscopic examination and the left ones were hydrolyzed and assayed for hydroxyproline

Measurement of collagen fibril diameter

After dissection the specimens were fixed in 1 per cent osmium tetroxide solution in 0 2 M veronal acetate buffer, pH 7 4 dehydrated through a graded series of ethanol and embedded in Epon 812 Ultrathin sections were cut with glass knives on an ultramicrotome (Porter Blum MT 2) The sections were stained with uranyl acetate and examined under the electron microscope (Hitachi HS 7D type) with an accelerated voltage of 50 KV and a direct magnification of 30 000

Four areas in every section were selected at random and three arbitrarily selected portions of each area were photographed Collagen fibril diameter was determined by calculating an average value for 300 fibrils obtained on twelve randomly selected visual fields Standard polystyrene particles with a constant diameter (910 A) were always photographed under the same conditions as were used for the examination of tissue specimens

Analysis of collagen content

The determination of collagen content was performed according to the method reported by Woessner in 1961 The specimens were weighed immediately after dissection hydrolyzed with 6N HCl and neutralized with 2 5N NaOH The samples were centrifuged at 3 000 rev/min for 5 minutes after removing impurities with an equivalent mixture of activated charcoal and Dowex 1 The supernatants and hydroxyproline standard solution (100 μg/ml) were oxidized with chloramine T which was then destroyed by perchloric acid After paradimethylaminobenzaldehyde solution was added and the tubes shaken they were placed in a 60° C water bath for 20 minutes and then cooled in tap water for 5 minutes After the developed color became stable, the absorbancy of the solutions was determined spectrophotometrically at 557 mμ

Collagen content was expressed as the amount of hydroxyproline measured

All calculations were subjected to statistical analysis using Student s *t* test

RESULTS

Collagen fibril diameter

The collagen fibril diameter of the hip joint capsule tended to increase gradually

Table 1 Influence of age and sex on collagen fibril diameter of hip joint capsule in Wistar rat

Age (weeks)	Fibril diameter (A) Male	Female
3	409 1 ± 60 6 (6)	380 9 ± 55 7 (6)
5	514 4 ± 25 4 (7)	470 1 ± 54 9 (7)
10	535 7 ± 65 2 (5)	503 2 ± 73 8 (5)
20	553 0 ± 44 3 (5)	509 5 ± 57 9 (5)
30	571 4 ± 50 0 (3)	522 9 ± 67 3 (3)

Values are presented as means ± s e the number of animals is given in parentheses

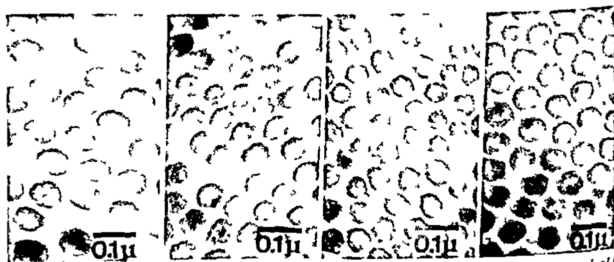


Figure 1 Electron microscopic findings of collagen fibrils of hip joint capsules in 10 week old ovariectomized Wistar rats with or without hormone treatment (A) not treated (B) treated with estrogen (C) treated with a combination of estrogen and progesterone (d) treated with progesterone

Table 2 Effect of gonadectomy and hormone replacement on collagen fibril diameter of hip joint capsule

Exp group	No of animals	Body wt (g)	Fibril diameter (Å)
1 Sham OVX	8	158 ± 16	533 6 ± 71 3
2 OVX	16	169 ± 15	559 5 ± 86 1
3 OVX+EB	16	151 ± 19	448 6 ± 93 4
4 OVX+EB+P	8	137 ± 13	452 8 ± 45 4
5 OVX+P	7	168 ± 31	535 9 ± 67 5
6 Sham TX	8	232 ± 31	535 2 ± 63 5
7 TX	13	199 ± 24	556 7 ± 86 4
8 TX+T	14	218 ± 21	567 6 ± 63 4
9 TX+P	7	232 ± 19	572 2 ± 48 6
10 TX+EB+P	2	203 ± 11	509 5 ± 35 4

OVX Ovariectomy
TX Orchiectomy
EB Estradiol Benzoate 20 μg/rat twice a week.
T Testosterone Propionate 2 5 mg/rat twice a week
P Progesterone 10 mg/rat twice a week

Values are presented as means ± s e
P value $P < 0.001$ 2 vs 4
$P < 0.01$ 2 vs 3
$P < 0.05$ 1 vs 4 3 vs 5, 4 vs 5

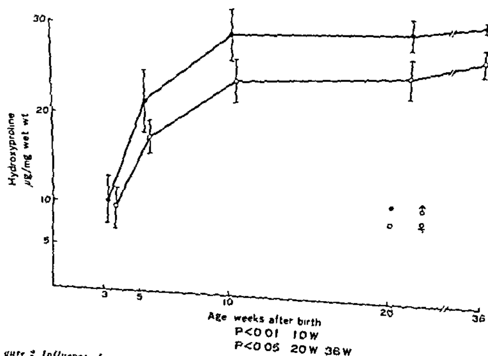


Figure 2 Influence of age and sex on collagen content of hip joint capsule in Wistar rat Standard errors of means of hydroxyproline content are indicated by vertical lines

Table 3 Influence of age and sex on collagen content of hip joint capsule in the Wistar rat

Age (weeks)	Hydroxyproline (μg/mg wet wt)	
	Male	Female
3	10 22 ± 2 99 (6)	9 69 ± 2 39 (6)
5	20 87 ± 3 60 (7)	17 77 ± 1 91 (7)
10	28 63 ± 2 90 (6)	24 11 ± 2 32* (5)
20	29 73 ± 0 84 (5)	25 61 ± 1 04** (5)
36	30 47 ± 0 50 (3)	26 54 ± 1 62** (3)

Values are presented as means ± s e , the number of animals is given in parentheses
* Statistically significantly different from males at $P < 0.01$
** Statistically significantly different from males at $P < 0.05$

Table 4 Influence of age and sex on collagen content of knee joint capsule in the Wistar rat

Age (weeks)	Hydroxyproline (μg/mg wet wt)	
	Male	Female
3	4 26 ± 1 29 (6)	2 92 ± 1 01 (6)
5	4 37 ± 1 12 (7)	4 01 ± 0 31 (7)
10	9 19 ± 1 27 (5)	6 64 ± 1 39 (5)
20	9 24 ± 0 31 (5)	7 54 ± 0 35*(5)

Values are presented as means ± s e the number of animals is given in parentheses
* Statistically significantly different from males at $P < 0.05$

with aging in both sexes There was no significant sex difference in the fibril diameter, although it was larger in males than in females at any period examined (Table 1)

Following the administration of estrogen, or estrogen combined with progesterone, the fibril diameter was significantly decreased in the ovariectomized female rats In the orchiectomized male rats, the fibril diameter was considerably increased by the administration of either progesterone or testosterone, whereas it was markedly decreased following the administration of estrogen combined with progesterone (Table 2, Figure 1)

Table 5 Effect of gonadectomy and hormone replacement on collagen content of hip joint capsule

Exp group		No of animals	Body wt (g)	Hydroxyproline μg/mg wet wt
1	Sham OVX	12	156 ± 13	23 78 ± 2 10
2	OVX	28	180 ± 18	25 06 ± 2 83
3	OVX+EB	24	132 ± 11	22 97 ± 3 11
4	OVX+EB+P	14	133 ± 16	21 72 ± 3 15
5	OVX+P	13	176 ± 25	28 64 ± 3 [illegible]
6	OVX+T	14	182 ± 17	28 21 ± 2 13
7	Sham TX	8	232 ± 31	28 14 ± 3 49
8	TX	14	197 ± 24	25 85 ± 1 28
9	TX+T	14	218 ± 21	29 11 ± 4 [illegible]
10	TX+P	12	227 ± 19	25 35 ± 2 30
11	TX+EB+P	14	177 ± 16	22 12 ± 4 08
12	TX+EB	13	152 ± 19	24 09 ± 2 96

OVX Ovariectomy
TX Orchiectomy
EB Estradiol Benzoate 20 μg/rat twice a week
T Testosterone Propionate 2 5 mg/rat twice a week
P Progesterone 10 mg/rat twice a week

Values are presented as means ± s e
P value $P < 0.001$ 1 vs 6 1 vs 5 2 vs 6 3 vs 5 3 vs 6 4 vs 5 4 vs 6 9 vs 11
$P < 0.01$ 2 vs 4 8 vs 11 7 vs 11 9 vs 12
$P < 0.05$ 2 vs 3 7 vs 12 8 vs 9 9 vs 10 10 vs 11 7 vs 9 7 vs 10

Table 6 Effect of gonadectomy and hormone replacement on collagen content of knee joint capsule

Exp group	No of animals	Body wt (g)	Hydroxyproline µg/mg wet wt
1 Sham OVX	6	149 ± 9	4.93 ± 0.90
2 OVX	25	179 ± 20	6.58 ± 1.13
3 OVX+EB	15	129 ± 10	5.30 ± 1.29
4 OVX+EB+P	14	133 ± 16	4.63 ± 1.02
5 OVX+P	13	176 ± 25	6.05 ± 1.44
6 OVX+T	14	182 ± 17	8.72 ± 2.34
7 Sham TX	4	218 ± 15	8.53 ± 1.37
8 TX	12	197 ± 19	6.77 ± 2.15
9 TX+T	9	214 ± 9	7.89 ± 0.83
10 TX+P	12	227 ± 19	5.77 ± 0.63
11 TX+EB+P	14	177 ± 16	3.73 ± 0.48
12 TX+EB	13	152 ± 19	4.18 ± 1.04

OVX Ovariectomy
TX Orchiectomy
EB Estradiol Benzoate 20 µg/rat twice a week
T Testosterone Propionate 2.5 mg/rat twice a week
P Progesterone 10 mg/rat twice a week.

Values are presented as means ± s.e.
P value $P < 0.001$ 1 vs 6 1 vs 5 2 vs 6 3 vs 5 3 vs 6 4 vs 5 4 vs 6 9 vs 11
$P < 0.01$ 2 vs 4 8 vs 11 7 vs 11 9 vs 12
$P < 0.05$ 2 vs 3 7 vs 12 8 vs 9 9 vs 10 10 vs 11 7 vs 9 7 vs 10

Collagen content

As the age advanced collagen content per unit wet weight of the hip joint capsule gradually increased up to the stage of sexual maturation but not after that and it was significantly greater in males than in females at 10, 20 and 36 weeks of age (Table 3, Figure 2). In the knee joint capsule there were similar tendencies to those observed in the hip joint capsule, although collagen content per unit wet weight was less in the former than in the latter (Table 4).

The collagen content was significantly increased by ovariectomy and decreased by the administration of estrogen or estrogen combined with progesterone while it was significantly increased by the administration of progesterone or testosterone alone in the ovariectomized rats (Table 5).

The collagen content of the knee joint capsule was also significantly increased by ovariectomy with or without administration of testosterone but it was significantly decreased by the administration of estrogen or estrogen combined with progesterone in the ovariectomized female rats (Table 6).

DISCUSSION

There have been conflicting views concerning the effect of sex hormones on connective tissue metabolism. The general consensus however seems to be that collagen accumulation is greater in males than in females (Fischer 1973). This opinion is well documented by the present study, i.e. collagen content per unit wet weight of the joint capsule is significantly greater in males than in females after the stage of sexual maturation. The influence of sex hormones on collagen content is also well demonstrated by the fact that the collagen content is approx

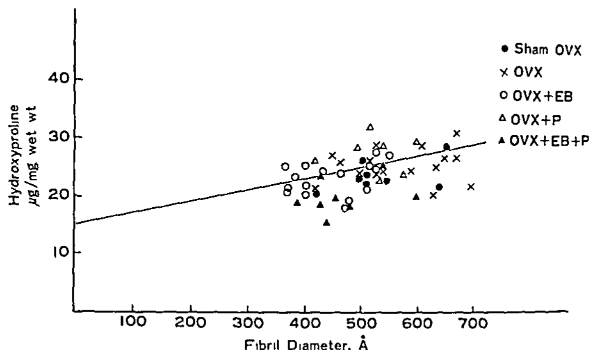


Figure 3 Correlation between collagen content and fibril diameter of hip joint capsule in female Wistar rat

imated in both sexes after gonadectomy

It has been said that estrogen accelerates collagen synthesis in the rat uterus (Kao et al 1964) and in rat bone (Orimo et al 1971), whereas it inhibits collagen synthesis in the rat tail tendon (Fischer 1973) It is made clear by the present study that the collagen content of both hip and knee joint capsule is significantly decreased by estrogen or estrogen combined with progesterone It is not known whether the decrease is derived from the inhibition of collagen synthesis or the stimulation of collagen degradation

The results of the present experiment indicate that there is a close interrelationship between collagen content and fibril diameter in the joint capsule A positive correlation between them is found statistically in females (Figure 3) However, factors that control collagen fibril diameter have not been elucidated It has been stated that there might be an inverse relationship between collagen fibril diameter and collagen hexose content, and that the location of the hexose on specific hydroxylysine residues might hinder the formation of intermolecular cross-links (Grant et al 1969, Morgan et al 1970) Estrogen, or estrogen combined with progesterone, is supposed to influence the glycosylation of these residues but this remains to be clarified

Biological and morphological changes of collagen fibers such as those mentioned above may result in changes in the mechanical properties of the connective tissue Therefore, it is probable that an imbalance of estrogen metabolism is related to relaxation of the hip joint capsule, although the relaxation may not necessarily be the primary etiological factor in congenital dislocation of the hip

ACKNOWLEDGMENT

Our sincere thanks go to Dr Tetsuo Ito Professor of Orthopedic Surgery Kyoto University School of Medicine for valuable advice and constructive criticism to Dr Kimio Yasuhira Professor of Pathology Chest Disease Research Institute Kyoto University, for generous help and suggestions and to Dr Kozo Sano Chief of the

Orthope i c Department of Kansai Denryoku Hos p tal for kind encouragement

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Acta orthop scand 47, 480–485, 1976

INTRA-ARTICULAR INJECTION OF HIGH-MOLECULAR HYALURONIC ACID

An Experimental Study on Normal Adult Rabbit Knee Joints

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High molecular hyaluronic acid was injected repeatedly into normal knee joints of adult rabbits. Histologically the articular cartilage was not affected by this treatment. The content of chondroitin sulphate assessed by a histochemical method, was not altered and neither was the water content of the hyaline articular cartilage. On the other hand in the synovial membrane of joints treated with hyaluronic acid a diffuse infiltration of plasma cells and lymphocytes was observed indicating that the hyaluronic acid administered exerts its action via the synovial membrane.

Key words: articular cartilage, normal joints, hyaluronic acid implantation, synovial membrane

Accepted 29.vi.76

Hyaluronic acid is an essential component of synovial fluid and also of articular cartilage even if present in small amounts (Balazs et al. 1966, 1974, Hardingham & Muir 1972, Laurent 1972, Sundblad 1970). Its physical properties have been studied *in vitro* by Balazs (1974) who has shown, among other things, that high-molecular hyaluronic acid inhibits lymphocyte migration. The phagocyting and chemotactic capacities of the leucocytes are also inhibited (Brandt 1974). It has also been demonstrated that the permeability of the synovial membrane is reduced by administration of hyaluronic acid (Sundblad 1953, 1970). The large hyaluronic acid molecule has a very strong water-binding capacity (Ogston 1966, Laurent 1972) and variations in its concentration in hyaline cartilage should influence the water content of this cartilage.

Hyaluronic acid has been prepared in a high-molecular form and is available as sodium hyaluronate with a molecular weight of about 1.5×10^6. However, its mechanism of action is still unknown. The aim of the present investigation was to study the effect of repeated injections of high-molecular hyaluronic acid into normal adult rabbit joints over a period of 8 weeks.

MATERIAL AND METHODS

Twelve adult Dutch rabbits, 24 months old and weighing about 1.5 kg, were used for the experiment. They were kept in cages with a floor area of 45 × 55 cm. An injection of 0.3 ml of high-molecular hyaluronic acid (Sodium hyaluronate concentration 10 mg per ml, produced by Phar

macia AB Uppsala Sweden) was given into the right knee joint under sterile conditions twice weekly over a period of 8 weeks The other knee was left untreated as a control The rabbits were allowed to move freely in their cages Four to five days after the last injection they were anaesthetized with urethane Both the treated and the control joints were dissected free and inspected macroscopically with special regard to any damage caused by the injection or the presence of infection Thereafter osteochondral specimens for histological and histochemical examination were taken from the femoral condyles with an oscillating saw Using a scalpel the articular cartilage was removed from the surface of the tibial condyles for determination of its water content Specimens intended for histological and histochemical examination were fixed in 10 per cent neutral formalin and specimens for water-content determination were immediately placed in weighed plastic tubes For histological evaluation of the synovial membrane specimens were taken from the anteromedial part of the joint capsule and fixed in formalin When all specimens had been removed the animal was killed with an overdose of urethane

After fixation the osteochondral preparations were decalcified in a mixture of formic acid and sodium citrate embedded in paraffin serial sectioned and stained with haematoxylin and eosin van Gieson s stain and Alcian blue at a magnesium chloride concentration of 0 4 M (Stockwell & Scott 1965) The synovial membrane was embedded in paraffin sectioned and stained with haematoxylin and eosin and van Gieson s stain

The cartilage specimens from the tibial condyles were weighed on a rapid weighing balance (Mettler H 20 T) with a precision of 0 1 mg They were then freeze dried to a stable weight and the percentage water content determined



Figure 1 The articular cartilage after repeated intra articular injections of hyaluronic acid is histologically normal

RESULTS

The rabbits showed no negative reactions to the repeated intra articular injections None of them died during the experimental period and no infections occurred in the injected knee joints When the joints were opened no signs of inflammation were seen macroscopically, but at the time of sacrifice several of the injected joints contained an increased amount of clear, very viscous fluid

Histological and histochemical examination

The hyaline articular cartilage and subchondral bone of both knee joints were histologically normal, as evaluated from serial sections stained with haematoxylin and eosin and van Gieson s stain (Figure 1) No growth of pannus over the cartilage surface or vascular invasion of the cartilage from the subchondral bone was observed Cartilage from the treated knee joint showed no deviations in territorial or inter territorial staining with Alcian blue at 0 4 M $MgCl_2$ as compared with cartilage from the untreated joint in the same animal

In the synovial membrane and sub-

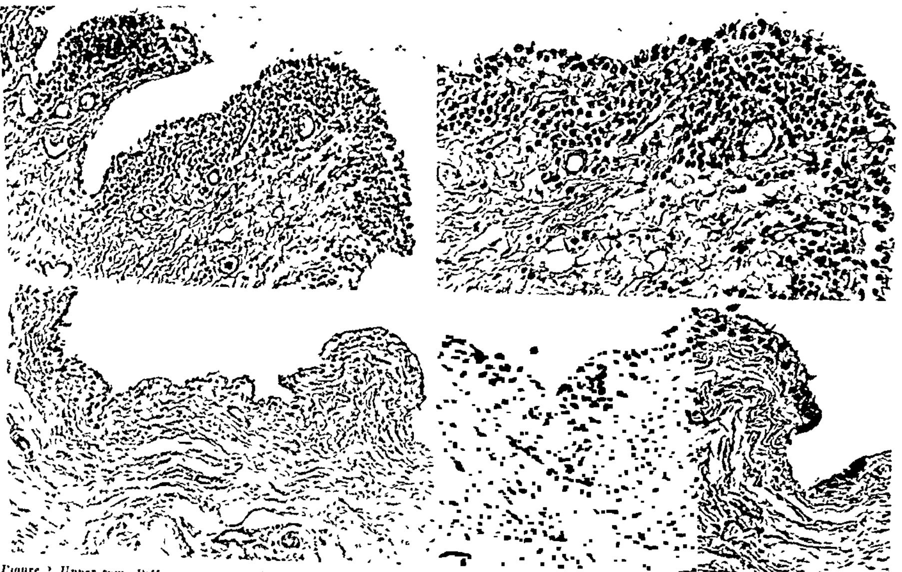


Figure 2 Upper row Diffuse invasion of basophilic mononuclear cells in the synovial membrane from a knee joint injected with hyaluronic acid *Lower row* For comparison, synovial membrane from the untreated control knee joint of the same rabbit



Figure 3 The basophilic mononuclear cells were identified as plasma cells and lymphocytes

Table 1 The water content of the articular cartilage after treatment with hyaluronic acid expressed as a percentage of that in the untreated control knee joint Implantation of high molecular hyaluronic acid into the joint did not affect the water content of the normal articular cartilage

Rabbit	Per cent
1	100 4
2	96 8
3	97 6
4	105 9
5	99 7
6	95 7
7	90 2
8	100 3
9	101 0
10	108 9
11	109 2
12	99 7

n = 12
mean = 100 5
S D = ± 5 45
95 per cent confidence interval = 97 0–103 9

synovial tissue of all treated joints there was diffuse infiltration of basophilic mononuclear cells (plasma cells and lymphocytes Figures 2 3) In addition occasional polymorphonuclear cells so called pseudoeosinophilic cells were seen No corresponding cellular infiltration was observed in the synovial membrane and subsynovial tissue from the contralateral untreated knee joints

Determination of water content

No difference in consistency between articular cartilage from hyaluronic acid treated knee joints and cartilage from untreated knee joints was noted on cutting the cartilage In Table 1 the water content of the cartilage from the hyaluronic acid treated joint is given as a percentage of that from the untreated joint There was no significant difference in this respect

DISCUSSION

It seems reasonable to assume that the clear and very viscous fluid observed in several knee joints treated with hyaluronic acid also contained hyaluronic acid This would indicate that the elimination time of hyaluronic acid when injected repeatedly into the knee joints of rabbits may be more than 4 5 days and also that the absence of findings in this study was not due to under dosage

High molecular hyaluronic acid has been found to have a favourable effect in various experimental articular cartilage injuries (Rydell & Balazs 1971 Wigren et al 1975) Good results in the treatment of traumatic arthritis in race-horses (Rydell et al 1970 Lindblad & Asheim 1974 personal communication) and of degenerative joint disease in man (Helfet

1974, Peyron & Balazs 1975, personal communication) have also been reported. The effect has been ascribed to the surface-protecting properties of the hyaluronic acid (Balazs et al 1966, Walker et al 1970, Sundblad 1970). Antonas et al (1973) demonstrated that intra-articularly injected hyaluronic acid was able to penetrate the articular cartilage of rabbits. The volumes injected (1–2 ml) have been shown, however, to cause a considerable increase in the intra-articular pressure (Wigren et al 1975), whereas the volume used in the present experiment does not increase the pressure in the rabbit knee joint (Wigren et al 1975). An intra-articular pressure increase can damage the joint (Smillie 1962) by causing distension injuries to the synovial membrane.

The normal histological appearance of the hyaline articular cartilage after repeated intra-articular injections of hyaluronic acid, over a period of 8 weeks, is consistent with the fact that *no injurious* effects of implantation of high molecular hyaluronic acid on articular cartilage have been observed previously. Alcian blue in the presence of 0.4 M MgCl —the histochemical method used in this study —mainly stains the chondroitin sulphate in the cartilage (Stockwell & Scott 1965). With this method no changes in the content of chondroitin sulphate in the cartilage of the joints treated with hyaluronic acid were seen. Had the hyaluronic acid been able to penetrate into the articular cartilage, which is improbable in view of its large molecular size, a reduced content of chondroitin sulphate might have been expected as Muir & Wiebkin (1973) have demonstrated *in vitro* that hyaluronic acid has an inhibitory effect on the synthesis of chondroitin sulphate in the chondrocyte.

The water content of articular cartilage, which normally is relatively constant in adult animals (Freeman 1972) is increased in osteoarthrosis (Mankin & Thrasher 1975). After immobilization of a joint in an adult animal this water content is reduced (Akeson et al 1974, Wigren 1975). The water content of the normal articular cartilage in the present experiment was not altered by repeated injections of hyaluronic acid, possibly due to the inability of the hydrophilic hyaluronic acid molecule to penetrate into the healthy articular cartilage.

The diffuse infiltration of basophilic mononuclear cells into the synovial membrane did not give rise to any macroscopic signs of inflammation. The reaction observed histologically could only partly have represented unspecific irritation, as a corresponding reaction occurred to only a minor extent after repeated injections of physiological saline (Falk 1974, personal communication).

In the latter study two equal sized groups of adult rabbits were injected intra-articularly with hyaluronic acid or saline. One hundred per cent of the hyaluronic acid injected joints showed moderate plasma cell infiltration of the synovial membrane while a similar though slight reaction was found in only 43 per cent of the saline injected joints.

The finding of infiltration of mononuclear cells is partly in accord with observations on synovial fluid from race horses treated with hyaluronic acid (Rydell et al 1970) and indicates that the effect of high molecular, intra-articularly implanted hyaluronic acid in certain types of osteoarthrosis and traumatic arthritis could be mediated via the synovial membrane. The synovial changes after repeated injections of hyaluronic acid over 8 weeks, together with previously observed effects on cells of the lymphomyeloid system *in vitro*, indicate that intra-articular administration of hyaluronic acid could influence the synovial membrane through a cellular mechanism and might therefore be worth testing in experimental and clinical synovitis. The question could be raised as to

whether the observed infiltration of plasma cells is an expression of an immunological reaction However, with the aid of the Passive Cutaneous Anaphylaxis test (Richter 1974), no formation of PCA reactive antibodies against this or other hyaluronic acid preparations was observed during or after immunization

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Acta orthop scand 47, 486–488, 1976

DIFFUSION OF TRANEXAMIC ACID TO THE JOINT

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Tranexamic acid (Cyklokapron, Kabi, Stockholm) in a dose of 10 mg per kg body weight was given i v to 17 patients at various intervals before operation on the knee joint, in order to elucidate the diffusion of the drug to the joint fluid and the synovial membrane The acid diffused rapidly to both the above tissues, and in the joint fluid it reached the same concentration as in the serum The biologic half time in the joint fluid was about 3 hours In the treatment of joint bleedings in hemophiliacs and in association with intra articular operations on such patients tranexamic acid is a suitable supplement to conventional substitution therapy

Key words hemarthrosis, hemophilia, tranexamic acid

Accepted 30 vi 76

Aminocaproic acid combined with replacement therapy has been used to minimize bleeding during orthopedic surgery on hemophiliacs, for example, in association with synovectomy (Storti et al 1972) Ahlberg (1970) has shown that aminocaproic acid given intravenously (i v) diffuses to the joint fluid and synovial membrane In the last few years aminocaproic acid has been superseded by a stronger antifibrinolysin, tranexamic acid, for the control of joint hemorrhages and loss of blood at operations on hemophiliacs Tranexamic acid has also been shown to prevent degradation of the cartilage matrix in animal experiments (Telhag 1973) and may be useful in the treatment of degenerative joint diseases in man However, the diffusion of tranexamic acid to the joint has not been investigated

MATERIAL AND METHODS

The series consisted of 17 patients (10 men and 7 women) aged 25–72 (average 48 9 years) Ten patients were to be operated because of ruptured meniscus of the knee joint and seven were to undergo synovectomy of the knee joint because of rheumatoid arthritis Tranexamic acid (Cyklokapron Kabi, Stockholm) was given slowly i v *in a dose of 10 mg per kg* body weight 1–17 hours before the operation At the operation all the synovial fluid was aspirated and a biopsy specimen of the synovial membrane was obtained The specimens were frozen at −20° C. Blood samples were collected immediately before the injection and at operation Serum was obtained by centrifugation and stored at −20° C until assayed The tranexamic acid in serum joint fluid and synovial membrane was determined according to Eriksson et al (1974)

RESULTS

The concentrations of tranexamic acid in serum, joint fluid and synovial membrane at different intervals after intravenous injection are given in *Table 1*

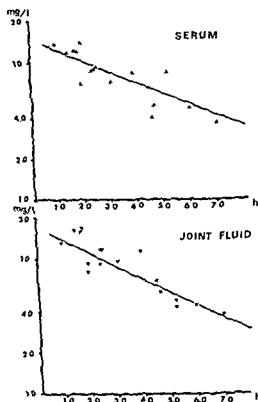


Figure 1. *Elimination of tranexamic acid from serum and joint fluid.*

Table 1. *Concentration of tranexamic acid in serum, joint fluid and joint membrane*

Patient (initials)	Hours after injection	Concentration of tranexamic acid (mg/l or kg) Serum	Joint fluid	Joint membr
E.T.*	1.00	13.8	13.0	11.4
B.M.M.	1.30	12.0	16.1	< 8.1
B.A.	1.45	12.4	15.7	< 8.5
K.O.	1.50	12.0	16.6	12.5
A.C.	2.00	13.8	9.1	< 5.5
H.L.*	2.00	7.0	7.8	8.3
M.T.	2.25	8.7	11.7	n.d.
S.B.	2.30	8.9	9.2	< 5.5
I.P.	2.35	9.5	11.4	n.d.
W.K.	3.10	7.2	9.5	< 3.5
A.H.	4.00	8.4	11.3	7.1
F.W.	4.35	3.9	6.8	< 5.9
N.P.	4.40	4.8	5.6	< 4.8
A.B.	5.15	8.3	4.5	4.4
I.P.	6.00	4.6	4.5	n.d.
E.M.	7.00	3.6	3.8	n.d.
S.K.*	10.50	< 0.5	< 0.5	2.5

* Patient with rheumatoid arthritis

The amount of synovial membrane obtained in 11 cases was not sufficient to permit exact quantitative determination of the concentration of the drug.

The biologic half time of tranexamic acid was calculated to be about 3.5 hours in the serum and about 3 hours in the joint fluid (Figure 1).

DISCUSSION

The fibrinolytic activity in the synovial membrane has been shown to be abnormally high in hemophilic arthropathy (Pandolfi et al. 1972). It was therefore thought to be of clinical interest to investigate whether tranexamic acid given i.v. diffuses to the joint fluid and/or the synovial membrane. The investigation showed that the drug diffuses rapidly to the joint fluid where it reaches the same concentration as that in the serum. No difference in this respect was found between patients with rupture of the meniscus and patients with rheumatoid arthritis. The drug was eliminated at roughly the same rate from the joint fluid as from the serum. The study did not allow any conclusions to be drawn about the concentration of tranexamic acid in the synovial membrane. However, the concentration tended to be initially lower than in the serum or joint fluid but elimination took place somewhat more slowly. The findings suggest that tranexamic acid is a suitable supplement to substitution therapy in the treatment of joint bleedings in hemophiliacs and in association with intra-articular operations on such patients. When given i.v. the drug diffuses rapidly into the joint fluid and synovial membrane which means that there is apparently no reason to inject it intra-articularly.

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Acta orthop scand. 47, 489–495, 1976

MECHANICAL PROPERTIES AND DENSITY OF BONE IN A CASE OF SEVERE ENDEMIC FLUOROSIS*

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Mechanical properties of 25 standardized specimens of compact bone from a 45 year old man with extreme endemic fluorosis were compared with similar specimens of nonfluorotic bone Data from dry and wet tested specimens were compared. Tensile strength, strain, energy absorbed to failure and modulus of elasticity were reduced in fluorotic specimens while compressive strength, strain and energy were increased in both wet and dry specimens Compressive properties exceeded tensile properties Drying increased tensile and compressive strength and modulus but decreased tensile and compressive strength and energy absorbed Dry specimens tended to follow Hooke's Law but wet specimens exhibited visco elastic behavior Wet fluorotic specimens had lower tensile properties but higher compressive properties and were more dense than fresh human compact bone

Key words human bone mechanical properties, fluorosis

Accepted 25 v 76

Although there is an abundant literature on the biological effects of fluoride—more than 16,000 publications in 35 years according to Faccini (1969)—little research has been done on its effects on the mechanical properties of bone The breaking strength of fluorotic bone in sheep was studied by Bell & Weir (1949) in dogs by Toshima & Tawara (1955) and by Henrikson et al (1970) in rats by Naylor & Wilson (1967), Saville (1967), Beary (1969), Rich & Feist (1970), Nordenberg et al (1971), and Wolinsky et al (1972), in rabbits by Faccini (1969), and in Japanese quail by Chan et al (1973)

However, a search of the available literature produced no references dealing with the effects of fluoride on the mechanical properties of human bone This is surprising in view of the widespread use of fluoride in the treatment and prevention of dental caries We were, therefore, pleased when an opportunity was presented to study the mechanical properties of human compact bone from a man with severe endemic fluorosis

* This research was supported in part by research grant AM03865 National Institutes of Health United States Public Health Service

** Present address Engineering Division Ford Motor Company Dearborn Michigan 48121 U S A J.L.W was a graduate student at the time the work was done

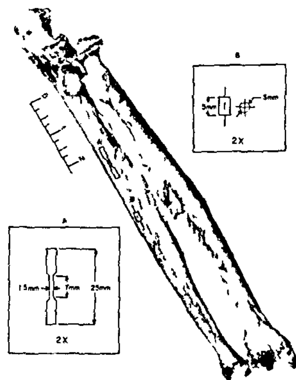


Figure 1. Left ulnar and radius from a 45 year old man with extreme endemic fluorosis showing shape and dimensions of test specimens.

MATERIALS AND METHODS

Material used in the present study consisted of fluorotic and nonfluorotic left ulnas and radii of middle aged men.

The fluorotic bones from a 45 year old Punjabi man were sent to us by Charles Nagant, M.D., Department of Medicine, St. Pierre Hospital, Catholic University, Leuven, Belgium, so that we could determine their mechanical properties. The nonfluorotic bones came from the osteological collection of the Department of Anatomy, The University of Michigan Medical School.

The Punjabi man had been almost completely bedridden for the 5 years preceding his death from primary urinary infection and secondary infection of extensive bed sores. He also had a severe endemic fluorosis accompanied by extensive skeletal changes which have been described by Singh et al. (1962). The water in his native village had 0.95 mg per cent or 9.5 ppm of fluorine. Considering that he lived to be 45 years of age and probably spent most of his life in the same village, the amount of fluorine he had consumed must have been enormous. The mid shaft of the radius had what appeared to be a healed fracture which was probably responsible for the large exostosis in the interosseous membrane (Figure 1).

Tensile and compressive test specimens of compact bone (Figure 1) from the fluorotic and the nonfluorotic bones were machined to a standardized size and shape with a No. 1000 Unimat equipped with a No. 1210 milling table. Only a few minutes were required to machine a test specimen and care was taken to prevent overheating and drying of the specimen during the process. Twenty five specimens from the fluorotic bones and a comparable number from the nonfluorotic bones were tested.

Ultimate tensile and compressive strength of the specimens were determined by loading them to failure at a constant rate of 1.27 mm/min in a floor model Instron testing machine equipped with a 22.68 kg load cell. The specimens were tested under pure tension or compression in the direction of their long axis which was parallel with that of the intact bone. Specially designed wedge shaped grips with Eastman 910 cement on the tabs were used to hold the specimens during a tensile test.

When mounting a specimen in the testing machine great care was taken to ensure that the specimen was perfectly aligned with the direction of the force so that during a test the force was uniformly distributed over the critical cross sectional area of the specimen. In the tensile specimens the critical cross sectional area was the reduced region but in the compression cubic specimens the cross sectional area was the same throughout the specimen.

Tensile strain (percent deformation) occurring in a specimen during a test was measured with Budd Metalfilm foil gages bonded directly to the specimen with Eastman 910 cement. Type C12-EXI-M-504-3 m/m gages with a resistance of 120 ohms and a gage factor of 2.01 were used. Compressive strain (percent deformation) was determined from differential movement of the specimen end surfaces and the cross heads of the testing machine.

From the stress and strain data obtained in a test, stress-strain curves were drawn from which the tangent modulus of elasticity, a measure of the stiffness of a material, and the energy the specimen absorbed to failure were computed. The modulus of elasticity or ratio between unit stress and unit strain was calculated from a tangent drawn to the straightest part of the stress-strain curve. The energy absorbed to failure was determined by measuring the area below a stress-strain curve with a compensating polar planimeter.

The effects of drying on the mechanical properties of the specimens was evaluated by testing

solution Among the fluorotic specimens, six were tested dry in tension and seven in compression while among the wet specimens, five were tested in tension and seven in compression Similar tests were performed on a comparable number of wet and dry specimens from nonfluorotic bones

Mechanical property values obtained from the wet fluorotic specimens are probably more truly representative of those in the living subject than the values for the dry tested specimens However data obtained from dry specimens are more useful for comparative purposes because both the fluorotic and the nonfluorotic specimens were obtained from bones that had been dry f r several years Comparable fresh material was unavailable

Because of the long period (5 years) during which the Indian man was bedridden and the known effects of immobilization on the density and mechanical properties of bone (Kazarian & von Gierke 1969 Fichler 1970 Krasnekh 1969) the density of the fluorotic and the nonfluorotic specimens was determined by weighing them in air and in Ringer's physiological saline solution Cubic compression specimens were used for the density determinations because it was easier to compute their volume than that of the irregularly shaped tensile specimens

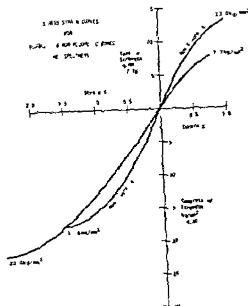


Figure 2 Average stress strain curves for five fluorotic and nonfluorotic wet specimens tested in tension and seven tested in compression

RESULTS

Mechanical Properties

From comparison of the stress strain curves for wet tested fluorotic and nonfluorotic specimens (Figure 2) it is seen that the fluorotic specimens had a lower tensile strength *and strain but a higher* compressive strength *and strain than the* nonfluorotic ones *The fluorotic* specimens also absorbed less energy *to failure* in tension (3 53 kg cm/cm³) than the *non*fluorotic specimens (8 10 *kg-cm/cm³*) However, in compression, more energy to failure was absorbed by the fluorotic (31 33 kg-cm/cm³) than by the nonfluorotic specimens (17 59 kg-cm/cm³)

Fluorotic specimens also had a *lower* modulus of elasticity (1,362 kg/mm²) *than the* nonfluorotic specimens (2,178 kg/mm²) This was indicated by the lower slope (53°) of the curve for the fluorotic specimens as compared with the slope (65°) of the nonfluorotic *ones* In each case the degree of the slope represents the angle between the straightest part of the stress-strain curve and the strain axis

When *the stress-strain* curves for dry tested *fluorotic* and nonfluorotic specimens *are compared* (Figure 3) it is seen again that the fluorotic specimens had a lower tensile strength and strain but a greater compressive strength and strain than the nonfluorotic ones Energy absorbed to failure in tension was also less in the fluorotic (2 83 kg-cm/cm³) than in the nonfluorotic specimens (5 03 kg cm/cm³) In compression, however, the situation is reversed, the fluorotic specimens absorbing 37 16 kg-cm/cm³ to failure compared to an absorption of only 8 64 kg-cm/cm³ for the nonfluorotic *specimens*

Again the slope of the curve for the fluorotic specimens was lower (65°) than that for the nonfluorotic (69°),

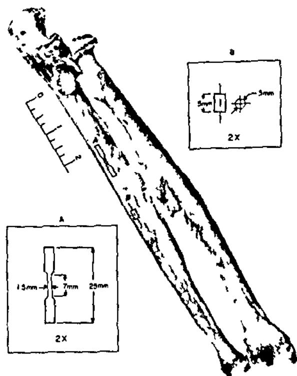


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some of them in the dry condition and others in the wet condition after they had been stored for several hours in Ringer's physiological saline solution Among the fluorotic specimens, six were tested dry in tension and seven in compression while among the wet specimens, five were tested in tension and seven in compression Similar tests were performed on a comparable number of wet and dry specimens from non fluorotic bones

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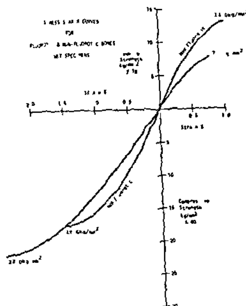


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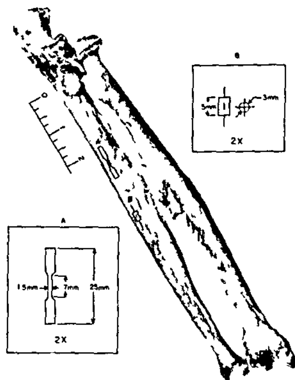


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The effects of drying on the mechanical properties of the specimens was evaluated by testing

fluorotic specimens also had a straight line to failure in tension but in compression the curve deviated from a straight line. Stress-strains for wet fluorotic and nonfluorotic specimens were sigmoidal in shape showing that wet bone has a visco elastic behavior.

Density

The average density of the fluorotic specimens was 2.01 g/cm³ for the dry ones and 2.26 g/cm³ for the wet ones in physiological saline. Similar dry specimens of nonfluorotic bone had an average density of 1.84 g/cm³. The density value for the dry specimens of both fluorotic and nonfluorotic bone is probably a more accurate value for density of osseous tissue than that of the wet specimens whose density is increased by moisture entrapped within the spaces of the bone.

DISCUSSION

In most cases, data on the effects of fluoride on bones of experimental animals are not directly comparable to ours for human bone because of species variations and differences in testing methods. According to Yamada (1970) and Evans (1973) there is considerable species variation in the mechanical properties of bone even when the specimens and testing methods are similar. Generally, in studies with experimental animals intact bones were tested in bending or in torsion. In both of these tests the bone is subjected to a combination of tension, compression and shearing forces which is quite different from our tests in which only one type of force was acting on the specimen. (For further information on stress distribution in bending or in torsion consult Harris (1963) or almost any other textbook on strength of materials.)

In addition to fluoride, the effects of reduced stresses on mechanical properties of bone must be considered because our fluorotic material came from a man who was bedridden for most of the last 5 years of his life.

Semb (1966) reports no significant differences in breaking strength (bending), modulus, and energy absorption between control and immobilized bones from dogs. However, Eichler (1970) found that the breaking strength of guinea pig femur, after 6 weeks of immobilization, was only 38 per cent of its original value, i.e. there had been a 62 per cent loss compared with the control bones.

Kazarian & von Gierke (1969) reported that the ultimate compressive load (kg) and deformation (mm) of lumbar vertebral bodies were two to three times less in specimens from monkeys immobilized in full body plaster of Paris casts for 60 days.

Apparently Nordenberg et al. (1971) are the only authors who have investigated the effect of fluoride combined with immobilization on mechanical properties of bone in experimental animals. They found that NA_2PO_3F decreased breaking (tensile) strain of standardized compact specimens from rat tibias but tensile strength and energy absorbing capacity were not significantly affected. Specimens from immobilized (osteoporotic) tibias also had no significant changes. Our data are not comparable because our specimens were not osteoporotic.

Comparison of our data with those given by Yamada (1970) revealed that ultimate tensile strength, tensile strain, energy absorbed to failure in tension, and modulus of elasticity of our wet fluorotic specimens were all less than those of fresh normal human bone. However, our fluorotic specimens had a greater ultimate compressive strength and compressive strain than fresh bone.

One of the known effects of the absence of stress on the skeleton is a decrease in bone density. According to

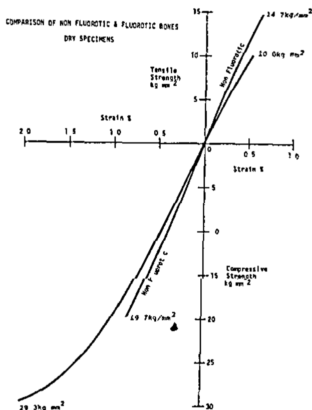


Figure 3 Average stress strain curves for six fluorotic and nonfluorotic dry specimens tested in tension and seven tested in compression

indicating that the latter had a higher modulus of elasticity Actual modulus values were 2,133 kg/mm² for the fluorotic and 2,666 kg/mm² for the nonfluorotic specimens

Effects of drying on the tensile and compressive properties of the fluorotic and the nonfluorotic specimens were also investigated

Comparison of the stress-strain curves for wet tested and dry tested fluorotic and nonfluorotic specimens (Figures 2 and 3) shows that the ultimate tensile and the ultimate compressive strength as well as the modulus of elasticity of both types of specimens were increased by drying The average modulus was 1,362 kg/mm² for the wet and 2,133 kg/mm² for the dry fluorotic specimens and 2,178 kg/mm² for the wet and 2,666 kg/mm² for the dry nonfluorotic specimens

However, *drying decreased the magnitude of the tensile and compressive strain in both fluorotic and nonfluorotic specimens* Thus, the average tensile strain was *approximately 0 75 per cent for the* wet and 0 55 per cent for the dry fluo*rotic specimens compared to an average* compressive strain of 3 0 per cent for the wet *and 2 per cent for the dry ones* Comparable values for nonfluorotic specimens *are 0 95 per cent for the wet and* 0 75 per cent for the dry specimens in *tension compared to 1 52 per cent for the* wet and 0 8 per cent for the dry ones in *compression*

Energy absorbed to failure by the wet *and the dry tensile tested fluorotic and* nonfluorotic specimens was decreased by *drying Wet fluorotic specimens ab*sorbed an average of 3 53 kg cm/cm³ of energy *while similar dry specimens ab*sorbed only 2 83 kg-cm/cm³ When *tested in compression wet fluorotic spe*cimens absorbed 34 33 kg cm/cm³ and *dry ones 37 16 kg-cm/cm³ of energy* to failure The difference was due to the *increased compressive strength* of the dry specimens

Dry nonfluorotic specimens tested in tension absorbed 5 03 kg cm/cm³ of en*ergy to failure compared* to an absorption of 8 10 kg-cm/cm³ of energy by the wet specimens When tested in compression the dry nonfluorotic specimens absorbed 8 64 kg cm/cm³ of energy to failure while the wet ones absorbed 17 59 kg-cm/cm³ of energy

The stress strain curves (Figures 2 and 3) also revealed that in both wet and dry tested fluorotic and nonfluorotic specimens ultimate strength, strain, and energy absorbed to failure were considerably greater in compression than in tension

The stress strain curve for the dry nonfluorotic specimens was *essentially a* straight line to failure in both tension and compression indicating a *marked* tendency to follow Hooke's Law Dry

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Kazarian & von Gierke (1969), this was seen in some astronauts after being in a prolonged zero G environment Thus in the 8 day Gemini 5 voyage the calcaneus and the metacarpal bones of both the pilot and the command pilot were reported to have a 20–30 per cent decrease in their density Prolonged hypodynamia alone or plaster cast immobilization can also cause disuse bone atrophy and decrease in density (Krasnykh 1969 Hancox 1972)

The density decrease found in the astronauts of the Gemini 5 flight differs from our fluorotic specimens in which the average density was 2 26 g/cm³ for the wet and 2 01 g/cm³ for the dry specimens These values are higher than any recorded by Blanton & Biggs (1968) for human compact bone except for the highest value of 2 100 g/cm³ and 2 00 g/cm³ found by Robinson and by Johnson respectively The maximum density value for our fluorotic specimens was 2 29 g/cm³ which as far as we know is considerably higher that that found for human bone by any other investigator Our density values strongly suggest that extreme endemic fluorosis increased the bone density of our subject in spite of any density decreasing effects of being bedridden for the last 5 years of his life

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investigations showed that the strain rate employed was sufficiently rapid to ensure that relaxation of stress during testing did not significantly alter the effective rate of application of stress although a limit of proportionality was attained at about 80 per cent of ultimate stress

MATERIALS AND METHODS

Compact bone tissue from 27 human right femora each excised post mortem and stored at — 20° C until required was studied The bones were obtained from 13 male and 14 female cadavera ranging in age from 19 to 87 years

The portion of femoral shaft extending approximately 10 cm toward the proximal extremity from about the bone midpoint was generally found to possess the greatest thickness of cortex and was therefore designated as material for production of mechanical test pieces

Preparation of tensile test pieces

At least one parallel sided plank of cortical bone with the long axis parallel to the femoral shaft was cut from each cross sectional quadrant (delineated as illustrated in Figure 1) of each femoral portion Cutting was carried out on the sliding table of a rotary blade macrotome equipped with parallel circular saw blades Figure 2) Ringers solution was employed as a coolant and lubricant The resultant planks were 6 cm in length 3 1 mm in thickness and with width corresponding to that of the bone cortex

With the aid of hardened templates each plank was quickly converted into a "waisted tensile test piece (Figure 3 b) of minimum width 3 8 mm Firstly the plank was located between the two templates in the manner illustrated in Figure 3 a

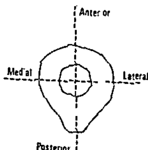


Figure 1 Delineation of femoral bone quadrants

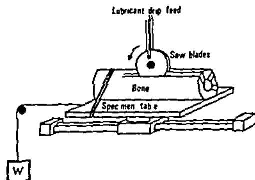


Figure 2 Macrotome sliding table arrangement

Screws linking the templates were then tightened and the whole assembly was carefully clamped in a vice Fine toothed files were employed to reduce the protruding portions of bone a half round file being used to shape the curved parts The completed test piece was released cleaned by brushing and by rinsing in water and then sealed in a polythene bag and stored at — 20° C.

Preparation of compressive test pieces

Parallel ended transverse sections of femoral shaft 7 5 mm in length were cut with the

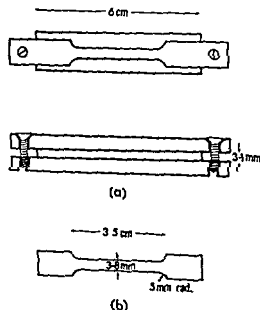


Figure 3 (a) Template production of tensile test piece (b) Dimensions of completed test piece

Acta orthop scand 47, 496–502, 1976

RELATIONS BETWEEN AGE, MINERAL DENSITY AND MECHANICAL PROPERTIES OF HUMAN FEMORAL COMPACTA

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Relations between mineralisation and mechanical properties have been investigated in human femoral compacta. Evidence of age related changes in physical properties of bone, independent of mineral density is provided by significant ($P < 0.05$) partial correlation between ultimate tensile stress and age. However, 75 per cent of variance in ultimate tensile stress and 85 per cent of variance in ultimate compressive stress could be accounted for by variation in mineral density.

Key words: bone, mineral density, mechanical properties

Accepted 20.v.76

Bone mineral content (defined as the mass of mineral per unit bone length) at certain sites in long bones, is commonly measured *in vivo* either radiographically (Keane et al. 1959, Doyle 1961, Mayo 1961, Anderson et al. 1966) or by gamma-ray absorption techniques (Sorenson & Cameron 1967, West & Reed 1970, Mazess 1971, Shimmins et al. 1972). The mineral value constitutes a measure of bone size and degree of mineralisation, and is related to bone strength. However, assessment of skeletal ability to fulfil a structural role requires that mineral content be satisfactorily normalised with respect to physical size of the subject. The most frequently adopted "normalisation" procedure involves division of mineral content by a parameter of physical size, such as the total bone width or length. Extension of this method entails the acquisition of data concerning the general population (Smith et al. 1969, Mazess & Cameron 1973), and subsequent deduction of "normal" ranges of normalised mineral content for males and females within different age groups. Such data, necessary for direct clinical interpretation of mineral value, requires continual revision to account for changing populations. Moreover, even the normalised values of quantity of bone present do not reflect the mechanical properties of bone tissue nor do they take account of the geometrical configuration of the bone. It is thus unlikely that such estimation alone will enable positive diagnosis of high susceptibility to fracture in more than a small percentage of cases.

In the present study, relations between mineral density, or mass of mineral per unit volume and mechanical properties of human femoral compacta, have been determined. Essentially static tensile and compressive tests were conducted. Initial

investigations showed that the strain rate employed was sufficiently rapid to ensure that "relaxation" of stress during testing did not significantly alter the effective rate of application of stress, although a limit of proportionality was attained at about 80 per cent of ultimate stress

MATERIALS AND METHODS

Compact bone tissue from 27 human right femora each excised post mortem and stored at —20° C until required was studied The bones were obtained from 13 male and 14 female cadavera ranging in age from 19 to 87 years

The portion of femoral shaft extending approximately 10 cm toward the proximal extremity from about the bone midpoint was generally found to possess the greatest thickness of cortex and was therefore designated as material for production of mechanical test pieces

Preparation of tensile test pieces

At least one parallel sided plank of cortical bone with the long axis parallel to the femoral shaft was cut from each cross sectional quadrant (delineated as illustrated in Figure 1) of each femoral portion Cutting was carried out on the sliding table of a rotary blade macrotome equipped with parallel circular saw blades (Figure 2) Ringers solution was employed as a coolant and lubricant The resultant planks were 6 cm in length 3 1 mm in thickness and with width corresponding to that of the bone cortex

With the aid of hardened templates, each plank was quickly converted into a "waisted" tensile test piece (Figure 3 b) of minimum width 3 8 mm Firstly the plank was located between the two templates in the manner illustrated in Figure 3 a

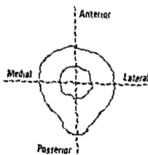


Figure 1 Delineation of femoral bone quadrants

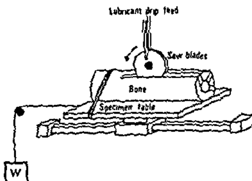


Figure 2 Macrotome sliding table arrangement

Screws linking the templates were then tightened and the whole assembly was carefully clamped in a vice Fine toothed files were employed to reduce the protruding portions of bone, a half round file being used to shape the curved parts The completed test piece was released cleaned by brushing and by rinsing in water, and then sealed in a polythene bag and stored at —20° C.

Preparation of compressive test pieces

Parallel ended transverse sections of femoral shaft, 7.5 mm in length, were cut with the

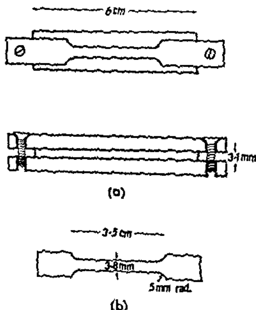


Figure 3 (a) Template production of tensile test piece (b) Dimensions of completed test piece

macrotome Then each section in turn was laid in a shallow trough containing Ringers' solution Using a bench mounted drilling machine and a diamond tipped core drill cylindrical compressive test pieces 5 1 mm in diameter and 7 5 mm in length were removed from each cross sectional quadrant Finally, specimens were separately sealed in polythene bags and stored at —20° C

Measurement of mineral content of mechanical test pieces

Mineral content at the midpoint of the long axis of each mechanical test piece was measured with a specially constructed iodine 125 miniature gamma ray absorptiometer Specimens were scanned in a shallow water bath to standardise for varying organic content The K value parameter of mineral content defined by Shimmins et al (1972) was evaluated from the dead time corrected transmission data This was converted to mineral content (mg/mm) using the calibration equation of Smith et al (1974)

Specimen dimensions were determined precisely with a micrometer prior to resealing in polythene bags and storage at —20° C

Methods of mechanical testing

All specimens were removed from the deep freezer between 1 and 3 h before testing During this time they remained sealed in the polythene bags and were allowed to attain room temperature without loss of moisture

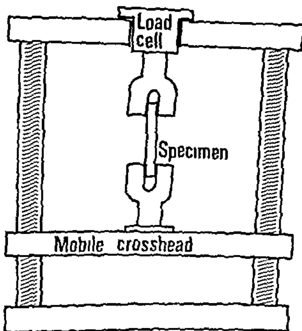


Figure 4 Experimental arrangement for tensile testing

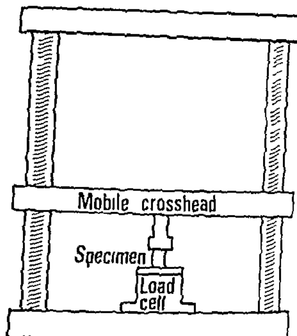


Figure 5 Experimental arrangement for compressive testing

Tensile and compressive tests were conducted with an Instron Universal Testing Machine Model No 1114 It comprises two vertical columns connected at top and bottom by rigid crossheads each equipped with a mount facilitating load cell installation Worm gears situated adjacent to both columns are used to vertically drive a mobile crosshead at predetermined velocity

In order to carry out tensile tests a load cell was mounted on the upper rigid crosshead Test pieces were held by two wedge type grips fixed to the load cell and mobile crosshead respectively (Figure 4) The mobile crosshead was then propelled downward at a rate of 2 mm/min This produced a specimen strain rate of approximately 10^{-3} sec^{-1} Each specimen was tested to destruction load being monitored by a potentiometric recorder incorporated in the Instron control console

For compressive testing a load cell equipped with a flat anvil was mounted on the lower rigid crosshead and a flat compression unit was attached to the underside of the mobile crosshead Each cylindrical test piece in turn was placed on end in the centre of the anvil (Figure 5) and stressed to destruction by driving the mobile crosshead downward The crosshead velocity of 0 5 mm/min produced approximately the same specimen strain rate as that which pertained during tensile testing Load was once again monitored with the Instron recorder

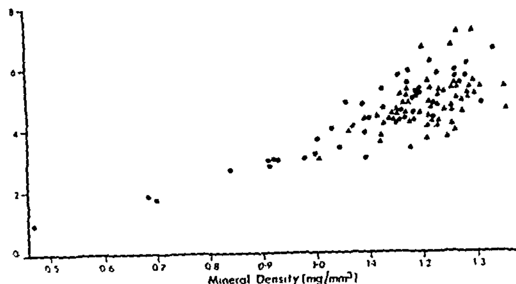


Figure 6 Ultimate tensile stress vs mineral density

RESULTS

Values of mineral content, tensile strength and compressive strength were each divided by specimen cross-sectional area to yield mineral density (M), ultimate tensile stress (σ_T), and ultimate compressive stress (σ_C) The latter two parameters were then considered in relation to the first Good exponential correlation was found in both cases (Figures 6 and 7), producing correlation coefficients r = 0 87 and r = 0 92 respectively (Table 1)

Mineral density, ultimate tensile stress and ultimate compressive stress, of the different bone quadrants were each in turn compared using the Student's paired t-test Generally, lowest values were found for specimens derived from the lateral/proximal quadrant, and highest values for those from the medial/anterior quadrant Moreover, these two quadrants had significantly different ($P < 0\ 05$) tensile strengths and mineral densities, the respective algebraic mean discrepancies being 17 3 per cent and 7 6 per cent

Table 1 Regression equations showing the relation of ultimate tensile and compressive stress to mineral density

Relations between ultimate stress σ (kg/mm²) and mineral density M (mg/mm³)	No of samples N	Correlation coefficient r	Index of determination r²
$\sigma_T = 0\ 524\,e^{1\ 761\ M}$	105	0 87	0 75
$\sigma_C = 0\ 547\,e^{2\ 017\ M}$	91	0 92	0 85

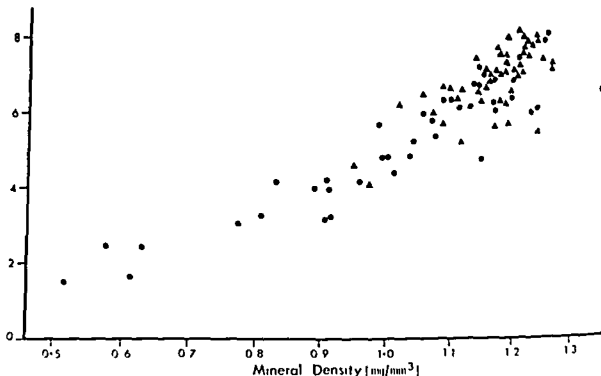


Figure 7 Ultimate compressive stress vs mineral density

In view of the differences between quadrants, average values of the parameters M, σ_T, and σ_C for specimens derived from all four quadrants were calculated these values were considered with relation to age of the subject Significant negative correlation of both average mineral density ($P < 0.05$) and average ultimate tensile stress ($P < 0.005$) with age was demonstrated (Table 2) Ultimate compressive stress did not change significantly with age ($P = 0.31$) Grand mean values calculated for all subjects studied were $M = 1.21 \pm 0.04$ mg/mm³ (2 × S E of Mean), $\sigma_T = 4.62 \pm 0.39$ kg/mm², $\sigma_C = 6.28 \pm 0.50$ kg/mm²

Finally, partial correlation between ultimate stress, mineral density and age was considered Coefficients of partial linear correlation are listed in Table 3

DISCUSSION

Measured values of ultimate tensile and compressive stress are lower than those reported by some other researchers

Table 2 Regression equations showing the relation of mineral density and ultimate tensile stress to age of the subject

Relations between mineral density M (mg/mm³) ultimate tensile stress σ_T (kg/mm²) and Age A (years)	No of samples N	Correlation coefficient r	Index of determination r²
$M = 1.37 - 0.0028\,A$	25	0 41	0 17
$\sigma_T = 7.47 - 0.0318\,A$	24	0 59	0 35

Table 3 Partial correlation of age mineralisation and mechanical properties

Nature of specimens	Coefficient of partial correlation rxy # between variables x and y with third variable # held constant	Level of significance P
Tensile test pieces	$r_{\sigma M\ A}$ = 0 76	$< 5\ 10^{4}$
	$r_{AM\ \sigma}$ = 0 12	n s
	$r_{A\sigma\ M}$ —0 47	$< 5\ 10^{2}$
Compressive test pieces	$r_{\sigma M\ A}$ = 0 92	≅ 0
	$r_{AM\ \sigma}$ = —0 24	n s
	$r_{A\sigma\ M}$ = 0 15	n s

n s not significant

(Dempster & Liddicoat 1952 Sedlin & Hirsch 1966 Melick & Miller 1966 Reilly et al 1974) This may be attributed to the relatively low strain rate and to the fact that comparatively fresh bones have been studied

The observed discrepancies between physical properties of different bone quadrants are broadly consistent with results published by Evans & Lebow (1951) and Evans (1964), with respect to sites in femur and tibia The need to ensure consistency of anatomical origin when comparing bone samples from different subjects is emphasised

It has been suggested that changes in size orientation and distribution of mineral crystallites are associated with structural deterioration of the skeleton in old age (Chatterji & Jeffery 1968 Chatterji et al 1972) Evidence supporting the concept of age related changes in bone physical properties unrelated to mineral density is provided when age is considered as an independent variable (Table 3) Significant ($P < 0\ 05$) partial correlation with ultimate tensile stress is established for specimens derived from subjects ranging from 19 to 87 years of age However the regression coefficient is small and accounts for only a small part of the total data variance

Total correlation and partial correlation of ultimate tensile stress and ultimate compressive stress with mineral density have been demonstrated (Tables 1 and 3) Indeed 75 per cent of variance in ultimate tensile stress and 85 per cent of variance in ultimate compressive stress can be accounted for by variation in mineral density This result is particularly important demonstrating that mineral density was the major determinant of strength in compact bone specimens studied Effects of variation in other physical properties of the collagenous bone matrix or the mineral inclusions must be either extremely small or alternatively be closely related to mineral density

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the help provided by staff of the Department of Clinical P [illegible] G [illegible] sl [illegible] M [illegible] credit is due to both Mr I Thom and Mr W Hyslop for construction of the miniature gamma ray absorptiometer We should also like to thank The National Fund for Research into Poliomyelitis and other Crippling Diseases for their financial support of this work.

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Acta orthop scand 47 503 508 1976

BONE MINERAL CONTENT AND MECHANICAL STRENGTH OF THE FEMORAL NECK

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The bone mineral content of the femoral neck of 61 autopsy specimens was assayed by x ray spectrophotometry The mechanical strength of the specimens was also determined experimentally by applying a compressive force perpendicularly to the shaft The ultimate force at fracture was obtained from force/displacement plots A coefficient of correlation of 0 89 between bone mineral content of the femoral neck and the ultimate force at fracture was found Even when limited to a group of women aged 67–80 a fairly close correlation was found This indicates that the bone mineral level measured *in vivo* can be used as a criterion of the risk of fracture in elderly women

Key words femoral neck mechanical strength bone mineral content x ray spectrophotometry

Accepted 18 x 76

The incidence of fracture of the femoral neck in females doubles every 5 years after the age of 60 and the cumulative risk at the age of 80 is 7 per cent (Bauer 1960) The genesis of femoral neck fracture is unclear but loss of bone mineral is often considered to be a significant factor

The assay of bone mineral *in vivo* has previously been difficult There has to be a loss of at least 30 per cent and in some cases 50 to 60 per cent of the calcium in the skeleton before rarefication can be established with certainty by the eye in routine radiographs (Lachman 1955) This method is consequently very inaccurate Using the x ray spectrophotometric method however the bone mineral in the femoral neck can now be determined *in vivo* with a precision of 1 9 per cent (Gustafsson et al 1974 Dalen & Jacobson 1974) The amount of bone mineral in the radiation beam is measured per unit area (mg/cm²) The attenuation by the soft tissues is compensated for by using two different radiation energies By scanning over a site, for example the femoral neck, the bone mineral content is obtained per unit length of the bone (mg/cm)

Since such direct measurements can be done it is of clinical interest to know to what extent the mechanical strength of the femoral neck can be assessed from the mineral content

MATERIAL AND METHODS

Altogether 61 specimens obtained from 54 women and 7 men were studied For 44 of the women the age range was 67–80 years

The specimens were measured less than 5 h after autopsy while in a moist condition

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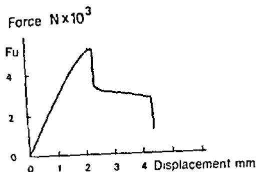


Figure 3 Typical force/displacement curve for the femoral neck. F_u denotes the ultimate force

resembled clinical subcapital fractures The rest of the specimens fractured in various other areas There was no statistically significant association between the various types of fractures and the mechanical strength of the bone or the above mentioned parameters

A typical force/displacement curve is shown in Figure 3 The general appearance of the curves obtained is in agreement with those obtained by other investigators (Currey 1970, Simkin & Robin 1973) The ultimate force, F_u, fracturing the femoral neck is taken as the peak value for the curve The mechanical strength of the specimen beyond this peak is due to the fact that an impact fracture was brought about

The correlations between the ultimate force and the mechanical properties are presented in Table 1, as are coefficients of correlation between bone mineral content and age

A plot of the ultimate force against bone mineral content for all the specimens is shown in Figure 4 The close correlation is not only due to the large age range of the material, this is apparent from the fact that there was no correlation between age and ultimate force fracturing the bones for women between the ages of 67 and 80 (Figure 5), whereas there was a correlation between the ultimate force and the bone mineral content for this age range (Figure 6)

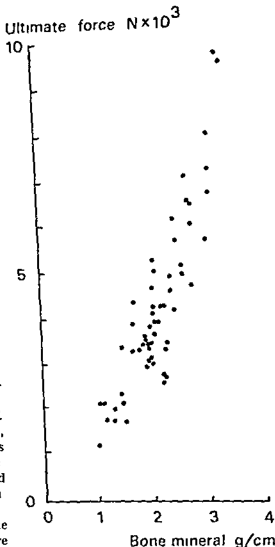


Figure 4 Ultimate force F_u as a function of bone mineral content for 51 women and 7 men aged 31 93 years $r = 0.89$

DISCUSSION

Studies of the femoral neck related to this investigation have been published previously Several investigators have reported a low bone mineral content or morphological signs of osteoporosis in patients with hip fractures (Alhava & Karjalainen 1973, Dequeker 1972, Foss & Byers 1972, Helelä et al 1969, Stevens et al 1962) Vose & Mack (1969) in an *in*

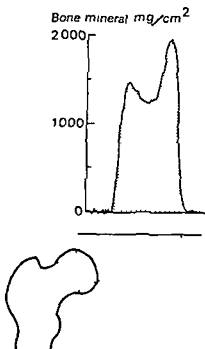


Figure 1 Distribution of bone mineral recorded by scanning perpendicularly to the femoral neck

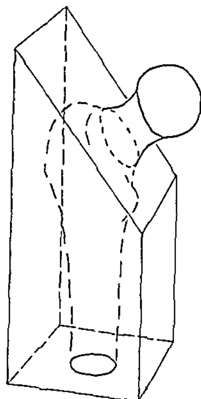


Figure 2 A plastic block moulded around the specimen leaving the neck and head free

The bone mineral content was determined by the x ray spectrophotometric method (Gustafsson et al 1974) The femur specimen was scanned perpendicularly to the neck axis (Figure 1) The profile so obtained was used to determine bone mineral content (and two mechanical parameters, J and M as defined in the appendix) The profile area is a direct measure of the bone mineral content per unit length of the scanned specimen

The strength of the femoral neck was determined experimentally A plastic block was moulded around the specimen (Figure 2) thereby supporting and preventing fractures in the lateral parts but leaving the neck and the head free A compressive force was applied to the head perpendicularly to the shaft with a speed of compression of 0 25 mm/s The force was measured with a strain gauge and the displacement of the head with a position gauge applied to the head by means of a separate mechanical transmission device A plot was made of the force as a function of the displacement obtained (Figure 3)

RESULTS

Of the 61 specimens, 37 fractured at the medial part of the neck, and the lesions

Table 1 Coefficients of correlation between ultimate force F_u and four different mechanical parameters Bone Mineral Content (BMC) BMC/Body weight J and M Correlations between bone mineral content and age are also given For the parameters J and M see appendix

	Correlation ultimate force to four different mechanical parameters				Correlation age to BMC
	BMC	BMC / Body weight	J	M	
All subjects	0 89	—	—	—	—0 59
Women 67–80 years	0 78	0 78	0 71	0 71	—0 02

the theoretical model (see appendix) used, since it describes any loading condition

It is remarkable that the more carefully analysed parameters, J and M, did not give closer correlations with bone strength than the simple parameter bone mineral content The reason may be that the bone tissue in the femoral neck is not homogeneous and does not have well-defined mechanical properties, and that the role of the organic tissue has not been taken into account in this study

The fairly close correlation between bone mineral content and mechanical strength of the femoral neck found in the present study indicates that it is possible to select patients with an increased fracture risk by x ray spectrophotometry It would be of interest to check this result with a prospective study of bone mineral content and fracture epidemiology If a correlation is found, as suspected, then high fracture risk patients should be treated prophylactically Various methods should be tested to determine their efficiency The effect of such therapy on the bone mineral content of individual patients can be followed with high precision by the x ray spectrophotometric method

APPENDIX

The strength of the femoral neck might not depend on the bone mineral content (mg/cm) only, but also on the distribution of the bone mineral within the cross section of the bone It is located mainly in the cortical part of the femoral neck where it forms an irregularly shaped pipe Therefore the femoral neck will be regarded here as a beam subjected to plane bending Standard formulas for mechanics of materials can then be applied Two parameters taking the distribution factor into account were used "mass moment of inertia , J, and a combined parameter, M

The mass moment of inertia J is calculated from

$$J = \int x^2 dm,$$

where x is the distance of the mass, dm from the neutral axis J is defined in analogy with the commonly used mechanical parameter moment of inertia

$$I = \int x^2 dA,$$

where x is the distance of the surface, dA, from the neutral axis The two parameters are related through

$$J = \rho_A I$$

where ρ_A is the density, assuming that this density is constant within the bone elements

The reason for using J instead of I in this study, is that J can be determined experimentally by x ray spectrophotometry, whereas I cannot easily be de-

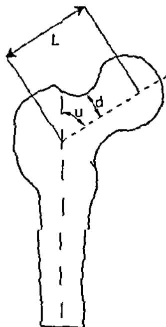


Figure 7 Length (L) and angle (u) of the femoral neck The distance (d) from the surface to the neutral axis is calculated from the distribution of the bone mineral in the cross section of the bone (see Figure 1)

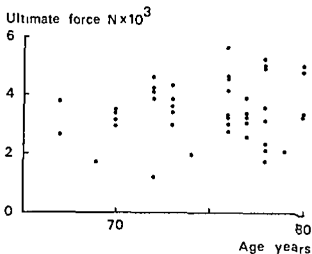


Figure 5 Ultimate force, F_u, as a function of age for 44 women, aged 67–80 years, r = 0 08

vitro study found a positive correlation between the roentgenographic density and the mechanical strength of 10 femoral necks Also, Schoenfeld et al (1974) found a correlation (r = 0 70) between the compressive strength and the apparent density of cancellous bone in femoral heads These studies show that the bone mineral content is of importance in the

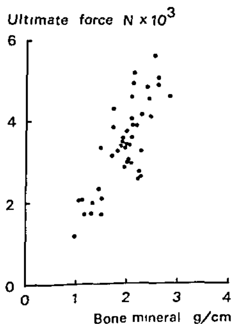


Figure 6 Ultimate force, F_u as a function of bone mineral content for 44 women aged 67–80 years, r = 0 78

mechanical strength of the femoral neck Phillips et al. (1975) developed a model to predict the failure load of femoral necks from measurements made on radiographs of the neck region

Many investigators have shown a close correlation between bone strength and bone mineral content, but they have usually not regarded the fact that both decrease with increasing age It is therefore more interesting to know the correlation within a narrow age group where osteoporotic cases are likely to be found and where significantly high values of bone mineral contents do not appear and "improve" the results

In this study, we have separately calculated the correlation between bone mineral content and mechanical strength for 44 women, aged 67–80 years It is evident from the results that neither the mechanical strength nor the bone mineral content are correlated with age in this group, whereas the bone mineral content and mechanical strength are correlated with each other (r = 0 78)

The correlation found is not caused by varying body weight, since the correlation coefficient is not changed if the parameters bone mineral content and ultimate force are corrected for the body weight (Table 1)

It might seem remarkable that in this study of women aged 67 80 no correlation was found between bone mineral content and age No conclusion regarding the change of bone mineral content with age can, however, be drawn from this cross-sectional study

The exact mechanism *in vivo* of femoral neck fractures is not known, and we have therefore not been able to reproduce the loading condition leading to femoral neck fractures *in vivo* (Backman 1957, Hirsch & Frankel 1960) Instead we found it more suitable to use a simple loading system which could easily be reproduced This however, does not prevent conclusions on the applicability of

Acta orthop scand 47, 509–514, 1976

SKELETAL MALFORMATIONS INDUCED BY MITOMYCIN C IN CHICK EMBRYOS

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One hundred and eighty chick embryos were studied for the presence of skeletal malformations after administration of mitomycin C at 72 96 and 120 hours of incubation Axial skeleton defects included those of ribs, vertebrae, beak and crania Appendicular skeletal defects were mainly confined to the lower limbs e g absence of phalanges, bent and shortened femur, fibula tibia and metatarsus, in that order Absence of phalanges and curved scapulae were noted in the upper limbs The length of femur, tibia and metatarsus was significantly reduced ($P < 0.001$) compared with the corresponding controls especially in the group treated at 96 h

Key words mitomycin C, chick embryos, skeletal defects, growth suppression

Accepted 30 xi 76

Mitomycin C, isolated from the broth of *Streptomyces caespitosus* (Hata et al 1956), is used clinically in the palliative treatment of various malignancies (Frank & Osterberg 1960, Evans 1961) It has been reported to be teratogenic in rats (Takaya 1965), mice (Yamura 1961, Ito 1967) and chicks (Kury & Craig 1967, Singh & Singh 1975) However, the skeletal defects as such have not been studied The present communication deals with observations made on mitomycin C induced skeletal malformations of chick embryos

MATERIALS AND METHODS

Fertile White Leghorn chicken eggs obtained locally from a Government poultry farm from a stock known to be nutritionally healthy and free from genetic defects were incubated at 37–38° C and at a relative humidity of 75–80 per cent The eggs were turned twice a day by a mechanical device in the incubator Mitomycin C (Kyowa Hakko Kokoya Co Ltd., Tokyo, Japan) was obtained from the local dealers For each batch of eggs, a fresh solution of mitomycin C was prepared in distilled water and injected aseptically into the yolk sac of the eggs, in various doses (20–24 µg/egg), at 72, 96 and 120 hours of incubation, using a simple technique described previously (Singh & Sinha 1973) Control eggs injected with distilled water were run with each batch of treated eggs The volume of injection was kept to 0.04 ml in all cases (treated and controls) The embryos were collected on the 18th day of incubation

One hundred and eighty treated and 50 control embryos were preserved in rectified spirit, cleared and stained with alizarin red S (Staples & Shnell 1963) for the study of skeletal elements The length of femur tibia and metatarsus of each embryo treated with 20 µg of mitomycin C in all three experimental groups was measured and statistically analysed to see the degree of suppression of growth in long bones as compared with their corresponding controls

termined *in vivo* Just as I is a measure of the bending strength, J is also under the given assumptions

The parameter M is a combined parameter, calculated in a similar way as J from simple cantilever beam theory It takes into account both the bending and compressive stress acting in the body It is calculated as

$$M = \left(\frac{L}{2} \frac{d}{J} \frac{\cos u}{} + \frac{\sin u}{m}\right)^{-1}$$

where L is the length of the femoral neck, m the bone mineral content of the femoral neck, u the angle of the femoral neck, and d the distance from the surface to the neutral axis as calculated from the distribution of the bone mineral in the cross section of the bone (Figures 2, 7) The formulas relate to homogeneous and elastic bodies It was thus assumed that the bone mineral content is proportional to the amount of bone tissue, and that the amount of bone tissue in a cross section is proportional to the area of the cross section

From x-ray spectrophotometry analysis m, J and M, defined as above, were computed The angle, u, between the neck and the shaft was obtained from radiographs (Figure 7) The correlations between the ultimate force fracturing the femoral neck and these parameters are presented in Table 1

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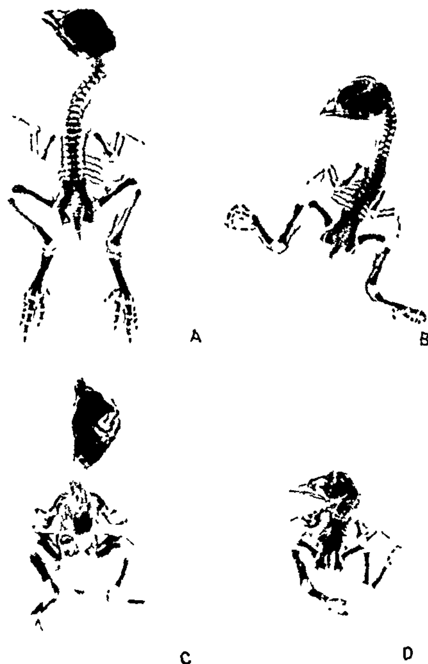


Figure 1 Skeletal malformations in chick embryos induced by mitomycin C (A = control)

RESULTS

Of the 180 chick embryos treated with mitomycin C, 99 (55 per cent) showed bony defects (Figure 1) The frequency of bony defects was highest in the series treated at 96 h of incubation with both doses (20 μg and 24 μg) used (Table 1) *Defects of the axial skeleton* included those of the beak, skull cap, vertebrae and ribs Rib anomalies were the most common (20 per cent) and included extra or absent ribs Defects in the beak (16 per cent) included parrot beak, cross beak or short (either upper or lower) beak while defects in the cranium included absence of skull cap, which was maximum (22 per cent) in the group treated at 96 h (Table 1) Vertebrae (14 per cent) were absent in variable numbers mostly in the group treated at 96 h of incubation

Table 1 Malformations of the axial skeleton of chick embryos induced by 20–24 μg of mitomycin C

Time of treatment	Embryos examined	Embryos abnormal	Beak	Vertebrae	Ribs	Crania
72 h	60	28	8 (29%)	2 (7%)	6 (22%)	4 (14%)
96 h	60	38	5 (13%)	9 (24%)	12 (32%)	8 (22%)
120 h	60	33	3 (9%)	3 (9%)	2 (6%)	1 (3%)
Total	180	99	16 (16%)	14 (14%)	20 (20%)	13 (13%)
Control	50	–	–	–	–	–

Amongst the defects of the appendicular skeleton those of hindlimbs were far more frequent. The bones affected in order of frequency were phalanges (81 per cent), femur (41 per cent), fibula (28 per cent), hip bone (27 per cent), tibia (13 per cent) and metatarsus (6 per cent) (Tables 2 and 3). The phalanges showed absence of ossification and in the hip bone there was absence of its pubic parts. The femur and tibia were mostly curved and shortened while the fibula was either shortened or absent. Most of the defects were bilateral. In the forelimbs only scapulae (30 per cent) and phalanges (40 per cent) were involved (Tables 2 and 3) but in one embryo all the bones of the forelimbs along with the other bones of the body were defective. The scapulae showed increased curvature and shortening *while in the* phalanges there was absence of ossification.

The degree of suppression of growth of the *femur, tibia* and *metatarsus* was highly significant ($P < 0.001$) when com

Table 2 Malformations of the limb bones of chick embryos induced by 20–24 μg of mitomycin C

Time of treatment	Embryos examined	Embryos abnormal	Scapula	Hip bone	Femur	Tibia	Fibula
72 h	60	28	11 (39%)	6 ([illegible])	16 (57%)	6 (22%)	11 (39%)
96 h	60	38	13 (36%)	16 (43%)	17 (45%)	5 (14%)	14 (37%)
120 h	60	33	6 (18%)	5 (15%)	8 (24%)	2 (6%)	3 (9%)
Total	180	99	30 (30%)	27 (27%)	41 (41%)	13 (13%)	28 (28%)
Control	50		–	–	–	–	–

Table 3 Skeletal malformations of the digits of chick embryos induced by 20–24 μg of mitomycin C

Time of treatment	Embryos examined	Embryos abnormal	Hand		Foot	
			Metacarpus	Phalanges	Metatarsus	Phalanges
72 h	60	28	–	3 (11%)	2 (7%)	18 (64%)
96 h	60	38		17 (45%)	2 (6%)	33 (90%)
120 h	60	33	–	20 (61%)	2 (6%)	30 (91%)
Total	180	99	–	40 (40%)	6 (6%)	81 (81%)
Control	50	–	–	–	–	–

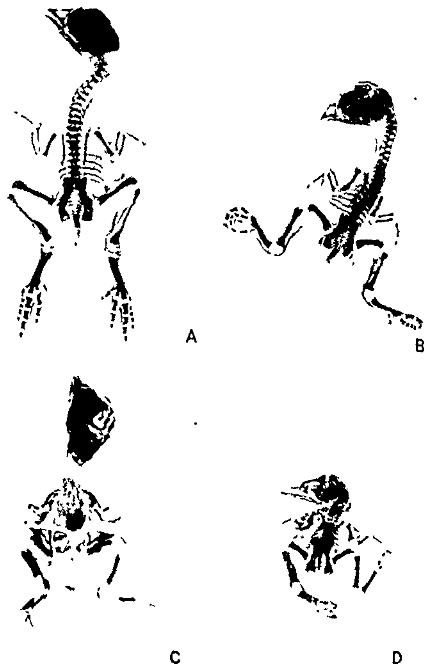


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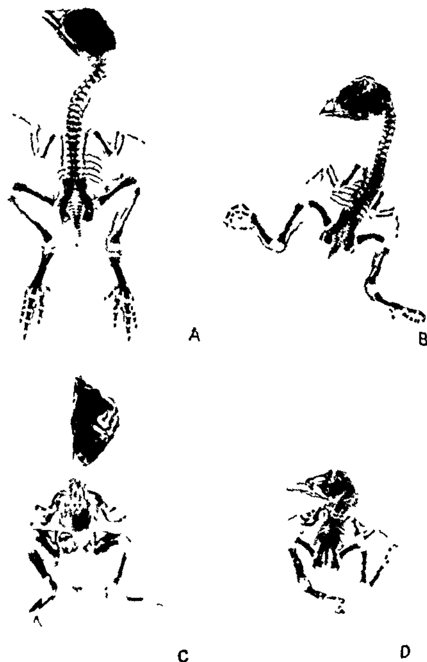


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development and rate of growth of the limbs Such a stage dependent sequence of bone involvement is known to occur (Singh & Sanyal 1974)

As regards the mechanism of action of mitomycin it primarily inhibits DNA synthesis and protein synthesis from their precursors in the living cells (Orstavik 1972) Its antimitotic activity has been observed to suppress cell growth in *vitro* (Singh et al 1974) and cartilage cells in particular are suppressed, as seen by their uptake of S^{35} (Singh et al 1975) and the marked shortening of treated bones ($P < 0.001$) may be explained on the basis of this suppression *of growth*

Inhibition of DNA synthesis in rapidly proliferating embryonic tissue when prolonged probably leads to localised cell death (Ritter et al 1971) which *per se* has also been associated with the process of normal development e g removal of excess cells in the shaping of organs (Glucksmann 1965 Saunders1966) and may accompany or precede congenital malformations (Menkes et al 1970) Cell death disrupts the normal mitotic pattern of tissues and destroys cell contacts and cell movements vital to normal tissue interactions and inductive events However dead cells may be removed and replaced by mitotically active cells which subsequently attempt to reconstitute the tissue or organ Such repair and regeneration is known to occur in fetuses after radiation damage (Hicks et al 1957, Sakurai 1968) and after radiomimetic drugs (Kreybig & Schmidt 1967, Chaube et al 1967 Singh & Sanyal 1974) The capacity for such regeneration and the ultimate outcome is dependent on the number of mitotically active cells that survive and the tissue remaining for such organogenesis This may account for the variable expression of the malformations induced by such drugs

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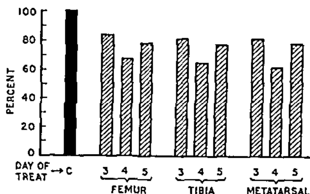


Figure 2 Suppressive effect of mitomycin C on growth of chick embryos

pared with the corresponding controls (Figure 2) in all the treated groups (Table 4) The group treated at 96 h showed the greatest degree of growth suppression ($P < 0\,001$ when compared with the 72 h group and $P < 0\,01$ when compared with the 120 h group, Table 4)

DISCUSSION

In a previous study mitomycin C proved lethal to 50 per cent of chick embryos treated on the 3rd through the 6th day of incubation besides inducing malformations in 59 per cent of the surviving embryos (Singh & Singh 1975) Limb anomalies including those of digits were most frequently encountered in the groups treated on the 4th and 5th days in that study Accordingly, the present study of skeletal defects was confined to this critical period of chick susceptibility to mitomycin treatment Treatment on the 4th day (96 h) was found to induce the maximum skeletal anomalies which is in agreement with the observations of Karnofsky (1955) Hindlimb bones were more frequently involved and the most affected part was the distal end of the extremities, i e , the phalanges Since the skeletal differentiation in the limbs, i e mesodermal condensation, chondrification and ossification, proceeds in a proximodistal sequence in general (Zwilling & Hansborough 1956, Amprino 1965 Milaire 1965), the suppressive effect of mitomycin on the proliferating and differentiating mesenchyme (Singh et al 1974, 1975) is likely to depend on the stage of differentiation of the limb buds at the time of the administration of the drug The skeletal elements which differentiate at an early stage will be more resistant than those which differentiate later Hence the long bones were less often affected While studying the effect of mitomycin C on developing chick embryos Kury & Craig (1967) found, in contrast to this study, that the tibia was the most commonly affected bone and the vertebrae and ribs were the least involved However, these discrepancies can be explained on the basis of the different species of chicks used since the teratogenic response in various species and strains is known to differ (Cahen 1964 Nogami 1964) Similarly skeletal anomalies in mice induced by mitomycin (Ito 1967) vary somewhat according to the species

The hindlimb bones were more involved than the forelimb bones this being related to the difference in time of initial

Table 4 Suppressive effect of 20 μg of mitomycin C on growth of bones of chick embryos

Time of treatment		72 h *	96 h *	120 h *	Control *
Femur	Mean	1 14 ± 0 22	0 92 ± 0 20	1 07 ± 0 17	1 36 ± 0 10
Tibia	Mean	1 55 ± 0 26	1 25 ± 0 24	1 49 ± 0 30	1 90 ± 0 17
Metatarsus	Mean	1 11 ± 0 22	0 86 ± 0 30	1 07 ± 0 26	1 36 ± 0 14

* $P < 0\,001$

Acta orthop scand 47 515–519 1976

EFFECT OF TANTALUM MARKERS ON LONGITUDINAL BONE GROWTH

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Small tantalum pins (0 50 × 1 5 mm and 0 32 × 1 2 mm) used as intraosseous radio-opaque markers were investigated for their effect on growth in 62 young rabbits The tetracycline growth method was used and a difference in daily growth rate between the marked right leg and the unmarked left leg indicated a slight growth stimulation The growth rate was slightly stimulated (at most 26 μm/day) on days 1 and 2 after insertion only if the larger markers were used No growth effects were detectable on days 12 and 21

Key words growth bone rabbit tetracycline skeletal marker tantalum

Accepted 27 iv 76

Metallic markers for growth determina [illegible]

met with several obstacles The marker has injured the bone resulting in loosening and even rejection of the implant (Hedstrom 1969) The instability of the marker has sometimes invalidated its use as a fixed reference point (Ryoppy 1965) The implantation technique has at times been traumatic involving operative interventions that have caused growth disturbances In general stimulating or retarding reactions have been seen in the marked bone and also secondary growth retarding reactions in the unmarked bones (Tapp 1966 Hansson 1967 Hedstrom 1969)

Bjork (1968) introduced a new type of intravital marker for use in roentgenography in clinical dentistry Small pins about 1 mm long made of vitallium or tantalum were reported to have been successfully used since 1951 in mandibular marking for growth studies A special instrument was constructed for implanting these pins into structures lying deeper than the mandibular to minimize the operative trauma of insertion and to facilitate correct placement (Aronson et al 1974) The instrument inserts the pin percutaneously with a cannula introduced into the bone

The present investigation used the tetracycline method (Hansson 1967) to study the growth effects of the implantation technique on the rabbit tibia

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Grants from Stiftelsen Svensk Våringsforskning and from the Funds of the University of Lund supported this investigation.

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Table 1 Effects on longitudinal growth of implantation of tantalum markers in the rabbit Difference in growth rate in μm/day for implanted right tibia and left tibia (unimplanted) control for same rabbit

Tantalum marker (mm)	Series	No of rabbits	Region for markers			Growth plate	Daily growth (μm ± S E M) Difference implanted right — left unimplanted control tibia Days in relation to implantation				
			Epiph prox	Metaph prox	Epiph dist		—1	1	2	12	21
0 50 × 1 5	1	16	×	×		Prox	0 ± 1	—1 ± 3	2 ± 2		
		4				Dist	5 ± 2	26 ± 6 *	20 ± 7		
	2	7	×		×	Prox	—2 ± 2	3 ± 3	0 ± 6		
						Dist	4 ± 1 †	16 ± 5 *	14 ± 5 *		
	3	6	×	×	×	Prox	—7 ± 2 *	—15 ± 6	—8 ± 4		
						Dist	1 ± 2	6 ± 6	3 ± 12		
	4	9	×		×	Prox				—2 ± 1	
						Dist				—6 ± 3	
	5	7	×		×	Prox					—4 ± 4
0 37 × 1 0	6	10	×	×		Prox	—4 ± 3	—4 ± 3	—4 ± 4		
						Dist	—1 ± 1	3 ± 4	2 ± 4		
	7	7	×		×	Prox	0 ± 2	—3 ± 2	—6 ± 1		
						Dist	0 ± 3	4 ± 2	4 ± 5		

* almost significant deviation from 0, $0 01 < P < 0 05$ (t test)
† significant deviation from 0, $0 001 < P < 0 01$ (t test)

MATERIAL

Sixty two rabbits aged 30 days were used, 1–2 litters for each series of investigations

METHODS

Insertion technique for tantalum pins

The rabbits were under neuroleptanalgesia Fluanizon and Phentanyl 6 and 0 12 mg/kg body weight (Hypnorm® Janssen, Belgium) Under fluoroscopic monitoring the pins were inserted percutaneously with a special implantation instrument (Aronson et al 1974) The tip of the instrument, a cannula, was introduced into the bone and when in the required position the spring loaded striking pin was released and the marker implanted in the bone In a few instances the cannula had to be introduced several times into the bone before the desired position was obtained

In the first series pins 0 50 × 1 5 mm were used The outer diameter of the cannula for these operations was 1 1 mm In the remaining two series tantalum pins 0 37 × 1 2 mm were inserted with cannulas of 0 7 mm outer diameter

Localization of pins

In all series one pin was placed in the proximal bony epiphysis of the right tibia A second pin was inserted either in the proximal metaphysis or in the distal bony epiphysis of the same tibia In one series three pins were inserted in the proximal and distal bony epiphysis and in the proximal metaphysis of the same tibia

Tetracycline growth measurements

Intravital marking of the bone was done with intravenous tetracycline (oxytetracycline, 5 mg/kg body weight) according to the method of Hansson (1967) Tetracycline becomes deposited in the bone and cartilage as a fluorescent band in the calcification zone of the growth plate As the bone grows the growth plate moves in the epiphyseal direction leaving the fluorescent band in the metaphysis A repeated injection of tetracycline will create a new fluorescent band The distance between the two bands is the endochondral longitudinal growth occurring between the two injection occasions Our measurement of the daily growth is accurate within 4 6 μm varying somewhat according to the investigated growth zone (Hansson 1967 Hansson et al 1973)

Timetable for experiments

Short term investigations (Series 1-3 & 7) Daily OTC injections were given on four consecutive days at intervals of 24 hours After the first interval, the tantalum pins were introduced into the bony epiphysis of the right tibia Longitudinal growth was thus obtained for a control day before and for two days after the pins were inserted The rabbits were killed 30 minutes after the last OTC injection, and the right pin marked tibia and the left unmarked control tibia were dissected free and prepared for growth measurements

Long term investigations In one series (no 4) growth on day 12 was investigated, in another series (no 5) growth was investigated on day 21

Processing of results

A *Local growth effect* The growth difference between the marked right leg and the unmarked left leg of each rabbit was computed separately as were the mean ± S E M for each series A difference in growth was indicated by the marking procedure Student's *t* test indicated whether the growth was statistically significant

B *Generalized growth effect* The lessening of growth rate during the two days after the marking procedure was computed as a percentage of the growth on the control day before marking The mean value of all measurements made on each day was computed as was the standard error

RESULTS

A Local growth effect

Table I summarizes the results according to pin size, localization of pins and duration of experiment

Control day The difference in growth rate on the control day varied between −7 and 5 μm/day Although statistically (almost) significant, this difference was biologically unimportant, as it coincided with the methodological error

Large pins (0 50 × 1 5 mm), short-term investigations

Pins in the proximal bony epiphyseal and metaphyseal region (Series 1) If the pins were inserted in the proximal epiphysis and metaphysis, there was no discernible effect on the daily growth

Insertion of the small pins caused no detectable difference in growth between the operated and the unoperated leg This trauma was thus less pronounced and so slight that growth disturbances were undetectable with the highly sensitive tetracycline method

The smaller cannula size of the insertion instrument combined with the increased technical skill in handling it that was acquired by the time the experiments with small pins began, contributed to the absence of demonstrable local growth effects from small pin insertion Small pins were therefore placed in correct positions in the bone more rapidly and more easily, thus lessening the operational trauma

The systemic decrease in growth rate found in this investigation is somewhat larger than that found in previous investigations (Hansson 1967) This is probably due to factors other than the insertion procedure itself Inhomogeneity of the rabbit material (different races, different breeders) and seasonal variations might explain the large standard deviation and also the larger decrease in growth

It is thus evident from this investigation that tantalum indicators are suitable for intravital marking in rabbit growth studies As slight local growth effects can be detected on the first 2 days after insertion but not after 12 days, it is recommended that growth studies should not be started until at least 2 weeks after insertion of markers

ACKNOWLEDGEMENT

The skilful technical assistance of Mrs G Sundin and B Sargava is gratefully acknowledged The investigation was supported by Landstinget M lan and Funds from the University of Lund English revision Francis Salisbury

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expressed as a difference between the proximal epiphyseal growth in the marked right leg and that in the control left leg In the distal growth zone however the marked leg showed a slight increase in growth being 26 and 20μm longer than that of the unmarked leg The difference was probably significant (Student s t test) for day 1

Pins in the proximal and distal epiphyses (Series 2) A slight increase in growth was found distally in the marked right leg the increase was probably significant on the two days after pin insertion

Pins in the epiphyses and in the metaphyseal region (Series 3) No significant difference was found in the daily growth between the marked right leg and the control left leg in either the proximal or the distal growth zones

Large pins long term investigations (Series 4 and 5) Neither type of marking either in the two epiphyses only or with a third pin in the diaphysis showed any significant difference in the daily growth on day 12 or 21

Small pins (0 37 × 1 2 mm) short term investigations

Pins in the proximal epiphyseal and metaphyseal region (Series 6) pins in the proximal and distal epiphyseal regions (Series 7) No significant difference in growth rate was observed in either type of experiment

B Systematic growth changes

By day 1 the growth rate had fallen 11 ± 8 per cent (S E) and by day 2 17 ± 10 per cent compared with the control day 1

DISCUSSION

The present study investigated whether the trauma of tantalum pin insertion was serious enough to invalidate the use of the pins for X ray growth studies Two factors could contribute to a local growth effect Firstly the operational trauma involving skin periosteal and bone penetration by the cannula holding the pin Secondly the local irritation of the pins A special histological study of the second factor showed that the tantalum indicators did not harm the bone the indicators were found to be fixed (Aronson et al to be published) These investigations lend no support to a tissue reaction of a magnitude that would disturb the growth by the presence of the tantalum indicators Growth effects are therefore more likely due to the trauma of insertion

Our findings show only a minor local growth effect when large pins are used A slight stimulation of the growth on the operated side was noted in the distal tibial growth zone when pins were inserted proximally it was also noted in the distal zone when pins were inserted in the two epiphyses These growth disturbances were transient and had disappeared by day 12 The statistically (almost) significant differences in two of the growth zones of the control day can be ignored as the differences coincided with the methodological error

These findings agree with previous investigations into experimental traumatic growth disturbances (Hansson 1967) The trauma most comparable with our pin insertion is the experimental *periosteal incision in the rabbit tibia* This trauma (compared with other major traumas such as medullary destruction and plugging of the marrow cavity) caused only a slight increase in the growth on the operated side compared with the unoperated side The magnitude of the local growth effect after periosteal incision was about the same as we found after insertion of large pins Compared with cortical and medullary traumas the growth effects after pin insertion are minute indicating that the trauma is slight



Figure 3A Osteoid osteoma In the nidus several amyelinic fibers are included in the fibrovascular tissue near the calcification focus



Figure 3B and C Isolated fibers (arrow) or fibers in groups of 3 5 within the calcified material only partially visible due to decalcification

changes in the vessel pressure being registered by the abundant innervation present (Golding 1954 Sherman & McFarland 1965) Another explanation would be direct irritation of the nerve fibers included in or near the calcification focus

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Figure 2 A Osteoblastoma of the rib There is an osteogenic reaction on the periphery with obvious amyelinic fibers going through the marrow spaces

calcified osteoid we could identify a great number of isolated amyelinic fibrils and attached to them typical Schwann cells (Figure 2 A) It was *not possible to identify* nervous structures in the completely calcified nidus

DISCUSSION

It is possible to detect innervation of benign osteogenic tumors (osteoid osteoma and osteoblastoma) with careful fixation techniques and decalcification and specific silver dyeing techniques of the Bielschovski type (Schulman & Dorfman 1970, Byers 1968)

The origin of the nerve fibrils described possibly depends on their localization If the nidus is located centrally it is reached by fibril branches penetrating the bone with the nutrient artery and accompanying the vessel branches (paravascular fibrils) or spreading into the bone marrow as independent fibers When the "nidus" is near the cortex or under the periosteum, the innervation comes from the fibrils following the haversian perivascular spaces and from the extraosseous periostic fibers, as observed in three or four of our cases and according to Schulman & Dorfman (1970)

The etiology of this obvious innervation is unknown Its distribution is similar to that of the glomus tumor

The pain associated with osteoid osteoma is generally explained as due to



Figure 2 B An isolated amyelinic fiber going through marrow spaces



Figure 3A Osteoid osteoma. In the nidus several amyelinic fibers are included in the fibrovascular tissue near the calcification focus



Figure 3B and C. Isolated fibers (arrow) or fibers in groups of 3 5 within the calcified material only partially visible due to decalcification

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Acta orthop scand 47 525–533 1976

POPLITEAL PTERYGIUM SYNDROME IN A 74-YEAR OLD WOMAN

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The case of a 74 year old woman with the rare popliteal pterygium syndrome is presented This syndrome is inherited as an autosomal dominant trait with incomplete penetrance and varying expression and consists of cleft lip and palate lip pits genital anomalies popliteal pterygium and malformations of the extremities The various treatments our patient underwent over the years are reported Treatment of popliteal pterygium involves special problems when removing the skin fold because the nerve and vascular cords lie immediately anterior to the posterior fibrous cord In the present case there are widespread arthrotic changes both in the extremity joints and in the spine These patients are short in stature This together with the general arthropathy suggests a hereditary metabolic disturbance in the cartilaginous tissue

Key words bone bone diseases developmental cleft lip cleft palate clubfoot growth disorders hereditary diseases pterygium syndactylia

Accepted 12 vii 76

The popliteal pterygium syndrome consists of multiple anomalies including cleft lip and palate *lip pits* genital anomalies popliteal pterygium and malformations of the extremities but the malformations vary greatly *in distribution* (Hecht & Jarvinen 1967 Gorlin et al 1968 Smith 1970 Sedano 1973) The syndrome is caused by gene *mutation* and is inherited as an autosomal *dominant* trait with incomplete penetrance and varying expression (Hecht & Jarvinen 1967 Gorlin et al 1968 Sedano 1973) About 30 cases have been published (Smith 1970) the first cases being reported during the latter part of the *nineteenth* century (Trélat 1869, Wolff 1889 Rydygier 1891, Busch 1891, 1892 Fischer 1893) The *popliteal* pterygium syndrome is diagnosed in infancy and early childhood (Champion & Cregan 1959)

The present case is interesting because of the many different malformations The case history from birth to the present—the patient is 74 years of age—is well known and documented moreover, the syndrome is interesting from the standpoint of the surgical treatment of the malformations of the extremities

CASE HISTORY

Female 74 years of age height 142 cm unmarried, *intelligence* normal (Figures 1 2)

Heredity She was the fifth born in a Swedish family of 10 siblings 4 *girls* and 6 boys One brother and one sister had conspicuously short

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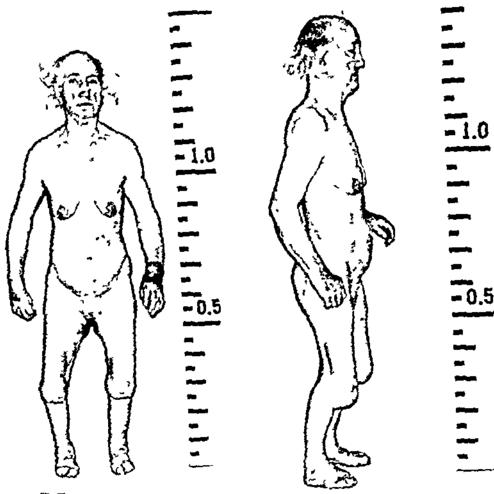


Figure 2 Photograph taken in 1973 at the age of 71 years Left Frontal view Right Side view

she could walk and run despite strongly bent knee joints When she was 4 an attempt was made to extirpate a small piece of the skin fold on the left side but the wound took 8 months to heal When she was 12 the extension defects were about 90° bilaterally (Figure 1) At this age bilateral exploration was carried out with the aid of longitudinal incisions laterally This revealed a fibrous cord and the sciatic nerve and vessels furthest dorsally in the skin fold but no tight musculature the operation areas were therefore closed During the next 2 years she was given correction treatment with plasters and splints Since then she has used lower limb braces but has also been able to walk without braces Bilaterally she has a deformity in the knee joints with the femoral condyles dislocated ventrally to the tibial condyles with considerable deformity of the femoral tibial and patellar joint surfaces and an extension defect of 20–30° bilaterally (Figures 2, 4) In both lower limbs there is also a varus deformity especially on the right side

2 Foot anomalies Primarily a considerable equinus deformity existed on both sides (Figure 1) this was corrected (Figure 2) On the left side there was also a valgus deformity and on the right side a varus deformity of the foot The toes—except for the big toe—are connected by a syndactyly with nail dysplasia and aplasia X rays show a hypoplasia of the tarsal skeleton and in the metatarsals dysplasia and aplasia also osseous fusions between the metatarsal bones and between the first phalanges (Figure 5) In



Figure 1. Photograph taken in 1914 at the age of 12 years. Left: Frontal view. Right: Side view.

hands and feet and another sister had syndactyly of the fingers. The father also had short hands and feet, moreover, his shoulder, on one side, was smaller from birth. The patient's paternal grandmother and great grandmother had short hands and feet, and were noticeably short in stature. The great grandmother was actually called a dwarf. The mother's side of the family was normal. The patient's parents were related, her mother and father had the same ancestor, who lived from 1685 to 1762.

Birth. After a normal pregnancy the patient was born in 1902 at home in Southern Sweden after a prolonged and difficult labour. She was judged to have a small chance of survival because of extensive anomalies.

Anomalies

A. Orofacial anomalies

1. Fused eyelids (ankyloblepharon filiforme ad natum). At birth a membrane between the eyelids was noted and cut bilaterally.

2. Cleft lip and palate (cheilo gnatho palato schisis) (Figure 3). When an adult the clef was operated on to close the defects. She ha now a posterior open cleft covered by an ob turator which improves her speech.

3. Lower lip pits. At birth bilateral pits wer found in the lower lip giving the impression o double lower lip. These pits were remove operatively at the age of 20.

4. Syngnathia. There were bands and mem branes between the left upper lip and the nas passage to the inside of the lower lip. These wer cut at birth.

5. Oral webbing. Webbing between the uppe and lower jaw on both sides was severed late in connection with operations in the oral cavity

B. Extremity anomalies

1. Popliteal pterygium (webbing). At birth a fold of skin was found stretching from th gluteal region and tuber ossis ischii to the heel bilaterally with considerable extension defect in the knee joint and also equinus foot. She began to walk on her knees at 2 years of age and soon

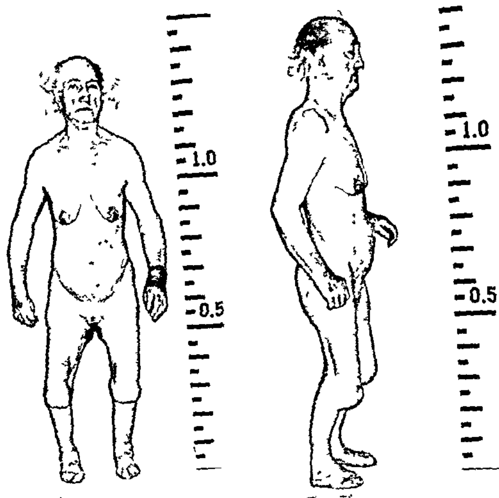


Figure 2 Photograph taken in 1973 at the age of 71 years Left Frontal view Right Side view

he could walk and run despite strongly bent knee joints When she was 4 an attempt was made to extirpate a small piece of the skin fold on the left side but the wound took 8 months to heal When she was 12 the extension defects were about 90° bilaterally (Figure 1) At this age bilateral exploration was carried out with the aid of longitudinal incisions laterally This revealed a fibrous cord and the sciatic nerve and vessels furthest dorsally in the skin fold but no tight musculature the operation areas were therefore closed During the next 2 years she was given correction treatment with plasters and splints Since then she has used lower limb braces but has also been able to walk without braces Bilaterally she has a deformity in the knee joints with the femoral condyles dislocated ventrally to the tibial condyles with considerable deformity of the femoral tibial and patellar joint surfaces and an extension defect of 20–30° bilaterally (Figures 2 4) In both lower limbs there is also a varus deformity especially on the right side

2 Foot anomalies Primarily a considerable equinus deformity existed on both sides (Figure 1) this was corrected (Figure 2) On the left side there was also a valgus deformity and on the right side a varus deformity of the foot The toes—except for the big toe—are connected by a syndactyly with nail dysplasia and aplasia X rays show a hypoplasia of the tarsal skeleton and in the metatarsals dysplasia and aplasia also osseous fusions between the metatarsal bones and between the first phalanges (Figure 5) In



Figure 3 Skull Roentgen examination AP view Note the cleft palate (arrow)

the foot region no operations were carried out instead the deformities were corrected with plasters and splints During adulthood hallux valgus has developed bilaterally

3 Hand anomalies At birth syndactyly was found in the hands between the middle and the ring fingers on both sides, and on the right side a hypoplasia of the thumb The metacarpal skeleton and the phalanges are shorter than normal and hypoplasia is found in the nail regions At the age of 4 years and again at 20 syndactyly operations were performed with good results X ray revealed that the right thumb is rudimentary especially the base of the first metacarpal bone (Figure 6)

C Genital and perineal anomalies

External and internal genitalia correspond to female sex Recent gynaecological examination showed virginal status She has hypotrophic labia majora vagina and uterus also hypertrophic clitoris There is a tendency for intercrural webbing Chromosome analysis of peripheral blood showed 46 chromosomes of normal female caryotype 46 xx

Menarche began at the age of 15 and menopause at 52 At 26 years of age she was operated for left sided benign ovarian tumour

D Skin changes

As mentioned nail dysplasia and aplasia are found in the hands and feet

On the trunk the back of the hands and lower arms there are multiple pigmented naevi The dermal ridge pattern, palmarly and plantarly stretches somewhat more towards the dorsal parts of the hands and feet than is normal but it is not found dorsally on the hands and feet

In adulthood she developed increasingly conspicuous male features as regards hair growth baldness on the crown beard on the face and masculine hair in the axillae and pubis regions (Figure 2) Laboratory investigation did not show abnormal increase in metabolites which would have indicated pathological androgen production

Radiography

A recent extensive roentgenological investigation (1972–1975) showed three types of skeletal changes

1 Congenital defects Cleft palate (Figure 3) thumb hypoplasia with a rudimentary base to metacarpal 1 dx (Figure 6) hypoplasia aplasia and osseous fusion of the metatarsal bones and of the phalanges (Figure 5)

2 Secondary changes (i e secondary to congenital anomalies) Deformity of the knee skeleton because of extension defects and pronounced secondary arthrosis development (Figure 4)



Figure 4 Left knee Roentgen examination Lateral view



Figure 5 Foot and ankle
A Right and left foot Photograph Dorsal view
B Right foot Roentgen examination AP view
C Right ankle Roentgen examination Lateral view





Deformities of the calcaneus and the foot skeleton because of an equinus position (Figure 5)

3 Other changes Apart from earlier reported anomalies and deformities there is general arthropathy with reduced articular cartilage pronounced osteophytes and periarticular calcifications in many joints Bilaterally the hip joints show an increased CE angle (Wiberg 1939) which has become even more pronounced because of considerable osteophyte formation in



Figure 3 Skull Roentgen examination AP view Note the cleft palate (arrow)

the foot region no operations were carried out instead, the deformities were corrected with plasters and splints During adulthood hallux valgus has developed bilaterally

3 Hand anomalies At birth syndactyly was found in the hands between the middle and the ring fingers on both sides and on the right side a hypoplasia of the thumb The metacarpal skeleton and the phalanges are shorter than normal and hypoplasia is found in the nail regions At the age of 4 years and again at 20 syndactyly operations were performed with good results X ray revealed that the right thumb is rudimentary especially the base of the first metacarpal bone (Figure 6)

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Figure 4 Left knee Roentgen examination Lateral view

The most obvious anomaly—popliteal pterygium or webbing (Patagium Flughautbildung)—has for a long time given the syndrome its name. The syndrome occurs with considerable variation, from insignificant anomalies difficult to discover to extremely extensive and serious anomalies. This has earlier been shown in families (Roselli & Gulienetti 1961, Klein 1962, Gorlin & Pindborg 1964, Hecht & Jarvinen 1967). Therefore an investigation should be made of the family where a member with isolated defects can point to popliteal pterygium syndrome. Thus it can be reasonably suspected that considerably more persons have this syndrome, complete or incomplete, than are reported in the literature, where the account as a rule refers only to cases with severe deformities or to families with members that have varying deformities. A larger proportion of the published cases come from Central Europe and from the USA (Gorlin et al. 1968), whereas no earlier case has been reported from the Scandinavian countries.

Naturally, the literature mostly describes children, as it is usually noted during the newborn period; therefore it is interesting to be able to report the present case from birth to old age. This has been possible because the various deformities and the treatment given have been carefully recorded both by the patient and the hospitals. Moreover, in this case the family tree is well documented as far back as 300 years because of an interest in genealogy in the family.

There are several instances that can suggest milder forms of popliteal pterygium syndrome in earlier generations and in the same generation, which agrees with the fact that the syndrome is inherited as autosomally dominant with incomplete penetration and varying expression (Hecht & Jarvinen 1967, Gorlin et al. 1968, Sedano 1973). Intermarriages are also earlier reported in the family.

The differential diagnostics in popliteal pterygium syndrome have been covered by Leiber & Olbrich (1966), Smith (1970), and Sedano (1973). The diagnosis in the severe cases does not seem to be difficult, whereas differential diagnostic difficulties exist where there are only a few anomalies or only orofacial anomalies, such as cleft lip and palate (Schonenberg 1955), because, according to Gorlin et al. (1968), there are about 20 different syndromes with this localized type of anomaly. This applies also to the other anomalies involved in popliteal pterygium syndrome although to a lesser degree, because the number of syndromes involved are fewer (Smith 1970). According to Sedano (1973), arthrogryposis multiplex congenita can be a differential diagnostic alternative for extremity anomalies with webbing, but in these cases, orofacial and peripheral extremity anomalies are lacking.

Congenital webbing is described in the literature in other localizations such as the elbow, shoulder, and neck region, either associated with popliteal pterygium (Matolcsy 1936, Kopits 1937) or as an isolated deformity (Schramm 1940, Shun Shin 1954, Smith 1970). Probably some of these are incomplete cases of popliteal pterygium syndrome, whereas others are of another genesis.

In the present case, some pigmented naevi were found on the trunk and the upper extremities, but these changes do not seem to differ in localization and size from what could normally be expected although it is said that these changes are pathognomonic of popliteal pterygium syndrome (Leiber & Olbrich 1966).

According to the literature, the treatment of orofacial anomalies has usually been surgical in by far the majority of cases, as it has in the present case. Syndactyly in the hands has usually been operated on in infancy and childhood.

The treatment of popliteal pterygium and the flexion contracture of the knee







Figure 6. Hand.
A. Right and left hand. Photograph. Dorsal view.
B. Right hand. Roentgen examination. AP view.

the acetabulum. In the spine there are generally severe spondylous changes.

Unrelated changes

In 1914 she had diphtheria. This was followed by bilateral otitis and mastoiditis. These were treated surgically on several occasions and resulted in severe reduction of her hearing bilaterally. In recent years slight diabetes mellitus, nontoxic goiter and cholelithiasis developed.

Social life

During childhood and adolescence her schooling was satisfactory. Later she had office training and worked in an office as a clerk for about 2 years. During the following years—up to the age of 50—she took care of her ageing parents. She was granted an orthopaedic disability pension when she was 30. Since 1964 she has lived alone in a modern flat on the first floor in a house with no elevator and has had the services of a home visitor for a few hours daily.

Up to the age of 70 she was able to walk both with and without braces for a distance of 2 kilometres. However, for the past 10 years she has used a stick and has been able to walk only about 300 metres.

Since the age of 20 she has experienced some temporary localized pain, but of low intensity, usually in the knees, the hips or the shoulders. This has shown a tendency to increase during the past 10 years but has not required analgesics.

DISCUSSION

The anomalies that exist in this case agree well with descriptions of popliteal pterygium syndrome and are considerably more extensive than the anomalies which, according to Sedano (1973), are required as minimum diagnostic criteria.

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joint and the equinus foot has varied considerably. In some cases the only treatment was braces (Dahmen 1962). Marquardt (1938) employed conservative treatment with traction and plasters. Operations were made on soft tissues (Kopits 1937, Aberle-Horstenegg 1938, Schramm 1940, Lewis 1948, Champion & Cregan 1959, Fèvre & Languepin 1962, 1966) and bone in the form of osteotomy or articular resection in the knee region (Hackenbroch 1924, Matolcsy 1936). In the present case, at exploration in 1944, it was noted bilaterally that furthest dorsally in the skin fold from tuber ossis ischii to the heel there was a fibrous cord next to the nerve and vascular cords, therefore a radical operation was judged impossible. Later, a corresponding observation was made by Kopits (1937), Lewis (1948), Champion & Cregan (1959), and Fèvre & Languepin (1962, 1966). Champion & Cregan (1959) succeeded, in both their patients, in eliminating the extension defect without jeopardizing the vascular and nerve cords by Z-plastic and extirpation of the dorsal fibrous cord.

During infancy and childhood, our patient had a bilateral equinus deformity with varus on the right side and valgus on the left. The equinus deformity was later almost completely eliminated by correction with plasters and splints, but this was probably also affected by the contracture treatment in the knee joint, as the dorsal fibrous cord is attached to the heel part.

The arthrosis development seen in most joints in our patient is easily accounted for, for instance, in the knee joints where there is marked deformity with ventral dislocation of the femur in relation to the tibia. This was probably caused partly by the fibrous structures seen in the skin fold, and partly by the contracture treatment. However, there are also noticeably advanced arthrotic changes, for instance, in the elbow joints, shoulder joints, and hip joints, and also in the spine. Hip changes with an increased CE angle were earlier described by Hecht & Jarvinen (1967), our patient has a larger CE angle than normal, and it has increased further due to osteophyte formation. The widespread arthrotic changes suggest a general metabolic arthropathy. This is also supported by the fact that patients with popliteal pterygium syndrome are short in stature probably due to a metabolic disturbance in the cartilaginous tissues, both in the growth plates and in the articular cartilage.

ACKNOWLEDGEMENTS

The authors express their sincere thanks to Miss Alfhild Runbäck for the material that she made available to them.

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Table 1 Cases of scoliosis associated with neurofibromatosis reported in the literature

Year	Author(s)	No of cases
1948	Haglestam collected from literature	77
1951	Kessel	2
1955	James	33
1959	Casman	3
1962	Philippart	16
1965	Scott	19
1969	Curtis et al	8
1972	Moe et al	55
1974	Biot et al	35
	Total from the literature	248
	Present reported series	98
	Total no of cases reported	346

(Veliskakis 1960) and spinal deformity, which was present in 100 per cent of cases (Table 4 Figure 1) The spinal lesions were in the form of scoliosis kyphosis or kyphoscoliosis but not lordosis (Table 5)

All the roentgenograms and notes of the 98 patients have been carefully examined and assessed Twenty three patients complained of pain seven were suffering from dyspnoea, and the deformity of the spine with or without one or both of the other two factors were the complaints of the remaining 60 cases (Table 6) The curvature of the spine was generally a short curve with the acute angle involving less than five vertebrae in the majority of cases Destruction and distortion of vertebrae were as a rule part of the radiographical picture (Figure 2) While scalloping of vertebrae and a widening of intervertebral foramina were rather common

Table 2 Incidence of neurofibromatosis in the two scoliosis series

Name of hospital	Total no of scoliosis cases	No of scolioses due to neuro fibromatosis	Per cent
Institut Calot Berck plage France	3017	89	3
Shafa Rehabilitation Hospital Tehran Iran	192	9	4½
Total	3209	98	Just over 3

Table 3 Age at the onset of scoliosis in neurofibromatosis

Age in years	No of patients	Per cent of patients
0–5	20	20
6–10	14	14
11–15	48	50
Over 16	13	12
Unknown	6	5

biopsies from destroyed vertebrae gave a positive picture of neurofibromatosis in only seven cases Lesions in bones other than the spine were seen in six cases (Figure 3) The curvature was in the cervical, thoracic and thoraco lumbar region but not in the lumbar region with the majority being in the thoracic region (Table 7) The convexity in 71 cases was to the right, a hump was present in 76 cases Details are recorded in Table 8

It is important to note that more than 50 per cent of scolioses due to neurofibromatosis first appear at approximately the same age as the idiopathic type But unlike the idiopathic form they involve a limit number of vertebrae generally producing a short acute angle curve with more rotation, severe distortion and in some cases a considerably more rapid progress

TREATMENT

All patients with curvature between 15° and 40° were treated with bracing and dynamic exercises For those who deteriorated under this regime surgical treatment was inevitable However, it was considered advisable to start surgical treatment without delay in patients whose curvature was over 60° Sixty-two cases received conservative treatment which consisted of bracing correction with localizer Risser cast or E D F Cotrel cast, together with active exercises Of these, 32 cases proved that their curve was stable even

Table 4 Criteria for diagnosis of neurofibromatosis

Criteria	No of patients	Per cent of patients
Family history	18	20
"Café au lait" spots (6 or more)	91	95
Neurofibroma	35	34
Spinal deformity	98	100

Acta orthop scand 47, 534–539, 1976

THE INCIDENCE OF SCOLIOSIS DUE TO NEUROFIBROMATOSIS

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Cobb in 1950 stated that a high proportion of scolioses classified as idiopathic, may be due to neurofibromatosis This paper describes a retrospective study of a series of 3209 scoliosis cases to determine the incidence of neurofibromatosis It was found to be just over 3 per cent Two different clinical pictures of scoliosis were seen among the neurofibromatosis cases

Key words scoliosis, neurofibromatosis

Accepted 22 iii 76

Neurofibromatosis or von Recklinghausen's disease is generally a dominant and rarely a recessive hereditary disease (Kleind 1970, Robert 1970) The exact aetiology is still unknown The incidence of the disease is one in 2500 3000 births The disease is characterised by neuromata, pigmented "cafe au lait" spots on the skin, visceral abnormalities and bone lesions Spinal deformity is the most frequent manifestation of bone involvement (Law & Pallis 1963, Cotrel 1970) The incidence of scoliosis associated with neurofibromatosis varies from 4 to 13 per cent in 248 cases reported in the literature (Table 1) (Hagelstam 1948, James 1955, Scott 1965, Moe et al 1972, Biot et al 1974)

In 1950, Cobb stated that a high proportion of scolioses classified as idiopathic may be due to neurofibromatosis The exact figure for such an incidence could not be found in the literature The purpose of this study was to determine the incidence of neurofibromatosis in a large series of 3209 cases of scoliosis

MATERIAL

In 1972 with the kind permission of Dr Cotrel the author had the opportunity to study retrospectively the details of the records and the roentgenogram and to examine a large number of the 3017 patients who had been admitted to the scoliosis service of the Institut Calot, Berck plage France during the previous 23 years To this were added a further 192 scoliosis patients who had been admitted to the Shafa Rehabilitation Hospital in Tehran in the previous 4 years

Altogether there were 98 cases of scoliosis due to neurofibromatosis in this series of 3209 scolioses The incidence in this series therefore is slightly over 3 per cent (Table 2) There were 51 girls and 47 boys and thus neither sex was dominant The age at the time of appearance of the scoliosis ranged from 6 months to 36 years However in the majority it occurred between 11 and 15 years (Table 3) The criteria for diagnosis were family history which was present in only 18 per cent of cases skin lesions neuromata, six or more café au lait spots or both

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Table 5 Type of spinal deformity in neurofibromatosis cases

Deformity	No of patients	Per cent of patients
Scoliosis	44	43
Kyphosis	2	2
Kyphoscoliosis	53	55
Lordosis	0	0

after discontinuation of treatment There has been little or no change in their condition even up to 10 23 years later It is important to realize that only curves under 50° remain stable with little change Among these patients there was a girl aged 14 years who had a typical scoliosis due to neurofibromatosis with a right thoracic curve between T_4 and T_{11} of 97° She developed paraplegia at the age of 17 years at the level of T_6 Her symptoms were treated successfully with skeletal traction and cast Examination was carried out 13 years after discontinuation of treatment. Her spine was stable with a curve of 67° There were no neurological signs She had married and had two healthy daughters, aged 3 and 5 years who were without scoliosis Such an observation was rare indeed

Surgical treatment was carried out for all aggressive curves and also for all curves over 60° Surgery consisted essentially of posterior fusion with cancellous bone grafting in 27 cases with bone graft and Harrington instrumentation in 23 and with cancellous and cortical tibial bone graft (Cotrel special technique) in 11 cases (Figure 4) All patients had at least 9 months postoperative spinal immobilization in a body cast Good fusion was achieved in all except two cases Secondary operations were required for the repair of pseudoarthroses in these two cases

Complications of operative treatment

1 Death in one case due to cardiac arrest immediately after application of the body cast



Figure 3 Shows extensive destruction of the upper end of the humerus, ulnar and radius in a girl aged 9 years with severe thoracic scoliosis due to neurofibromatosis

2 Pseudoarthroses requiring a second operation in two cases

3 Deep infection with re-exploration in one case, superficial infection in four cases

4 Permanent paraplegia in two cases one in each series. In both cases Harrington instrumentation with mild correction had been carried out

Table 6 Functional complaints of neurofibromatosis patients

Complaint	No of patients	Per cent of patients
Pain	23	26
Shortness of breath (Dyspnoea)	7	5
Deformity	52	52
Combination of the above complaints	16	15

Table 7 Location of the curvatures in neurofibromatosis scoliosis

Location	No of patients	Per cent of patients
Cervical	5	5
Thoracic	75	75
Thoraco-lumbar	10	10
Lumbar	0	0
Combination of the above locations	8	8



Figure 1 Thoraco lumbar scoliosis with a large cafe au lait spot

Figure 2 Typical X rays of kyphoscoliosis due to neurofibromatosis showing severe distortion and acute angle curve a Anteroposterior view b Lateral view

formity of the spine appeared between 11 and 15 years of age. The minimum follow up period was one year and the maximum was 23 years.

A study of the development of these 98 cases revealed that at least two distinct forms of scoliosis due to neurofibromatosis could be traced. A moderate form, with a slow onset in the majority of cases, appears early in life between 5 and 10 years of age and responds comparatively well to conservative measures. Some 30 per cent of the cases were in this category. The other form, designated the "severe form", appears in most cases at a later age (10–15 years of age) and has a progressive onset. This form, even under the best orthopaedic management and bracing, deteriorates. It soon leads to severe kyphoscoliosis and unlike the idiopathic form it may lead to paraplegia. Unfortunately it has not been possible to find definite criteria for differentiating these two forms.

Spinal fusion was the treatment of choice for all cases with progressive curves and also for all curves over 60°. The goal of surgery must be prevention of aggravation rather than the correction of aggravated curves. Correction of curves under anaesthesia may lead to irreversible paraplegia and regrettable results.

ACKNOWLEDGEMENTS

I wish to express my deep appreciation to Dr. Y. Cotrel for his kindness and encouragement throughout this investigation. I would also like to thank my colleagues at the Shafa Hospital who allowed me to include their cases in this study.

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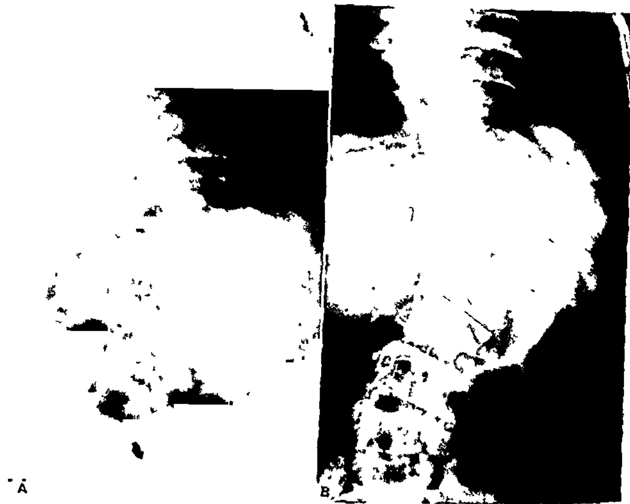


Figure 4 A typical acute angle curve in scoliosis due to neurofibromatosis a Preoperative b Post operative Note the heavy cancellous graft in the fusion area

Table 8 Details of the scoliosis in neurofibromatosis

	No of patients	Per cent of patients
Convexity to the		
Right	71	70
Left	8	8
Right and left	19	20
Measurement of the curve		
> 50°	16	15
< 50°	82	85
No of vertebrae involved		
> 5	68	70
< 5	30	30
Hump		
5 mm–15 cm	76	75
Rotation	68	70
+ ++++		

Immediately after the operation paraplegia ensued and removal of the Harrington rod in the second case did not change the neurological state In this case the actual tumour condition had eroded the lamina and the cord and dura were under the tumoral tissue It is thought that paraplegia in this case was the result of vascular damage due to the removal of tumour tissue However from this bitter experience it was learnt that correction should never be done under general anaesthesia

DISCUSSION

In this retrospective study of altogether 3209 scoliosis cases, 98 cases definitely due to neurofibromatosis were found Thus the incidence of neurofibromatosis scoliosis in this series is just over 3 per cent In the majority of cases the de-

body height using the formula introduced by Björe et al (1968)

Statistical methods The significance of observed intraindividual differences was tested by Student's t test for paired experiments using the method of least squares for calculating standard deviations A statistically significant difference caused by chance was 5 per cent or less

RESULTS

The VC and the MVV were lower than predicted normal values (Tables 2 and 3)

The effect of the application of the Milwaukee brace on the VC and MVV was examined in patients who had not been treated (Group I) and in patients who had been treated for some time with the Milwaukee brace (Group II) The mean values of the VC and MVV as a percentage of predicted values were slightly lower after the application of the Milwaukee brace in both groups The differences were statistically significant in the case of MVV (Table 2) There was no significant difference between the group that had been treated for some months with the Milwaukee brace and the one which had not been treated

Treatment with the Milwaukee brace for periods varying between 2 5 33 months (mean 15 months) did not change the VC or MVV, as a percentage of the predicted normal values when measurement was performed without the Milwaukee brace (Table 3)

During the period of treatment with the Milwaukee brace there were only minor changes in the scoliotic angle

DISCUSSION

Diminished VC in scoliotic patients was first reported by Schneevogt (1854) (cited by Caro & Dubois 1961) and was later confirmed by Gucker (1962) Flagstad & Kollman (1928) found that the VC was reduced to the greatest extent when the scoliotic curvature was localized in the thoracic spine The total lung capacity and its subdivisions were found by Chapman et al (1939) to be decreased in scoliosis The reduced total lung capacity the normal residual volume and intrapulmonary gas mixing with only a moderate reduction of the MVV, investigated by Ilicovici & Lyons (1956) and Bergofsky et al (1959) were considered to indicate that emphysematous changes of the lungs were not responsible for the impaired lung function

Reduced lung volumes were observed in young and adult patients alike, but

Table 3 Effect of treatment with Milwaukee brace on lung function

Mean vital capacity (VC and mean maximum voluntary ventilation at free rate (MVV) as a percentage of predicted normal values at the first examination and after a period of treatment mean 15 range 2 5-33 months) with the Milwaukee brace in a group of 16 scoliotic patients (Group II No Milwaukee brace was applied during the spirometric examination

	At first *examination*	After *treatment*	*D*
VC per cent of normal			
M	75 (63)	71 (66)	4* (2)
SD	± 14 3 (± 12 8)	± 13 1 (± 15 4)	
MVV per cent of normal			
M	73 (67)	[illegible]6 (69)	−3 (2)
SD	± 13 0 (± 15 1)	± 15 8 (± 18 0)	

D the mean difference between the first and second examination
Other symbols as in Table 2

spine in 5 patients. The convexity of the scoliotic curve was right sided in 24 patients. The deformity of the thorax and the spine was estimated clinically by one examiner (J.A.S.) according to a four grade scale: slight, moderate, pronounced and severe. It was considered moderate in 22 cases and pronounced in 7. The degree of deformity measured according to Cobb (1948) ranged between 28 and 105°. There were no cases of slight or severe deformities of the thorax in this material. The mean age of the patients at the time of the first examination was 15.3 years.

METHODS

General procedure. Spirometric examination of lung function was performed routinely in all patients in connection with their first visit as out-patients to the Department of Orthopaedic Surgery. The examination was performed regardless of the degree of scoliosis, the deformity of the thorax or the indication for treatment with a Milwaukee brace and before respiratory or other exercises were recommended. Some of the patients were treated with the Milwaukee brace immediately after the lung function examination (Group I) and some were observed for some time before treatment with the Milwaukee brace was introduced (Group II). The two groups were fairly similar with regard to the factors included in Table 1.

The examinations to study the immediate effect of application of the Milwaukee brace on lung function were performed in close succession, usually on the same day or within 2–3 days.

In 13 patients (Group I) this was done before treatment with the Milwaukee brace had started and in 16 patients (Group II) after 2.5–33 months (mean 15 months) of treatment.

The examinations to study the effect of treatment with the Milwaukee brace for several months (Group II) were made with an interval of 8.2–33 months and without the brace applied.

Lung function test. The vital capacity (VC) and the maximal voluntary ventilation at a free rate (MVV) were determined spirometrically using a Bernstein spirometer. The results of the VC and MVV measurements were expressed as a percentage of the predicted normal values (Birath et al. 1963, Grimby & Soderholm 1963, Bjure 1963). The normal values of lung function were calculated with and without correction of the body height for the scoliosis deformity. The angle of the scoliosis measured according to Cobb (1948) was used in the correction of the

Table 2. Effect of application of the Milwaukee brace on lung function

Means of vital capacity (VC) and maximum voluntary ventilation at a free rate (MVV) as a percentage of predicted normal values of patients examined without and with the application of the Milwaukee brace. Figures within brackets are calculated from corrected body height (17). Patients of Group I had not been treated with the Milwaukee brace before the measurements while the patients of Group II had been treated for 2.5–33 months (mean 15 months).

	Group I n = 13	Group II n = 16	Groups I + II n = 29
VC per cent of normal			
without M.br.	76 (69)	71 (66)	73 (67)
SD			14 (14.9)
with M.br.	73 (66)	70 (65)	71 (65)
SD			13.6 (13.9)
D	−3 (−3)	−1 (−1)	−2 (−2*)
MVV per cent of normal			
without M.br.	74 (68)	76 (69)	75 (69)
SD			14.3 (17.1)
with M.br.	65 (60)	72 (65)	69 (63)
SD			18.1 (15.5)
D	−9*** (−8***)	−4** (−4*)	−6*** (−6***)

D = the mean difference (with minus without Milwaukee brace)
n is the number of patients
* = 0.01 > P > 0.05 ** = 0.001 > P > 0.01 *** = P > 0.001
P is the probability that the difference was caused by chance

body height using the formula introduced by Iljure et al (1968)

Statistical methods The significance of observed *intraindividual differences* was tested by Student's t test for paired experiments using the *method of least squares* for calculating standard deviations A statistically significant difference caused by chance was 1 per cent or less

RESULTS

The VC and the MVV were lower than predicted normal values (Tables 2 and 3)

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Treatment with the Milwaukee brace for periods varying between 2 5 33 months (mean 15 months) did not change the VC or MVV, as a percentage of the *predicted normal* values, when measurement was performed without the Milwaukee brace (Table 3)

During the period of treatment with the Milwaukee brace there were only *minor changes* in the scoliotic angle

DISCUSSION

Diminished VC in scoliotic patients was first reported by Schneevogt (1854) (cited by Caro & Dubois 1961) and was later confirmed by Gucker (1962) Flagstad & Kollman (1928) found that the VC was reduced to the greatest extent when the scoliotic curvature was localized in the thoracic spine The total lung capacity and its *subdivisions were found* by Chapman et al (1939) to be decreased in scoliosis The reduced total lung capacity, the normal residual volume and intrapulmonary gas mixing with only a moderate reduction of the MVV, investigated by Iliecovici & Lyons (1956) and Bergofsky et al (1959), were considered to indicate that emphysematous changes of the lungs were not responsible for the impaired lung function

Reduced lung volumes were observed *in young and adult patients alike, but*

Table 3 Effect of treatment with Milwaukee brace on lung function

Mean vital capacity (VC) and mean maximum voluntary ventilation at free rate (MVV) as a percentage of predicted normal values at the first examination and *after a period of treatment* (mean 15 range 2 5 33 months) with the Milwaukee brace in a group of 10 scoliotic patients Group II No Milwaukee brace was applied during the spirometric examination

	At first examination	After treatment	D
VC per cent of normal			
M	75 (68)	71 (66)	4 (2)
SD	± 14 3 (± 12 8)	± 13 1 (± 15 4)	
MVV per cent of normal			
M	73 (67)	76 (69)	−3 (−2)
SD	± 13 0 (± 15 1)	± 15 8 (± 18 0)	

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METHODS

General procedure Spirometric examination of lung function was performed routinely in all patients in connection with their first visit as out patients to the Department of Orthopaedic Surgery The examination was performed regardless of the degree of scoliosis the deformity of the thorax or the indication for treatment with a Milwaukee brace and before respiratory or other exercises were recommended Some of the patients were treated with the Milwaukee brace immediately after the lung function examination (Group I) and some were observed for some time before treatment with the Milwaukee brace was introduced (Group II) The two groups were fairly similar with regard to the factors included in Table 1

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Lung function test The vital capacity (VC) and the maximal voluntary ventilation at a free rate (MVV) were determined spirometrically *using a Bernstein spirometer* The results of the VC and MVV measurements were expressed as a percentage of the predicted normal values (Birath et al 1963 Grimby & Söderholm 1963 Bjure 1963) The normal values of lung function were calculated with and without correction of the body height for the scoliosis deformity The angle of the scoliosis measured according to Cobb (1948) was used in the correction of the

Table 2 Effect of application of the Milwaukee brace on lung function

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	Group I n = 13	Group II n = 16	Groups I + II n = 29
VC per cent of normal			
without M br	76 (69)	71 (66)	73 (67)
SD			14 (14 9)
with M br	73 (66)	70 (65)	71 (65)
SD			13 6 (13 9)
D	–3 (–3)	1 (1)	2 (2*)
MVV per cent of normal			
without M br	74 (68)	76 (69)	75 (69)
SD			14 3 (17 1)
with M br	65 (60)	72 (65)	69 (63)
SD			18 1 (15 5)
D	9*** (–8***)	4** 4*)	6*** (6***)

D = the mean difference (with minus without Milwaukee brace)
n is the number of patients
* = 0 01 > P > 0 05, ** = 0 001 > P > 0 01 *** – P > 0 001
P is the probability that the difference was caused by chance

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whereas in young patients the thoracic cage was normally distensible, it was more rigid in older patients Caro & Dubois (1961) found that chest cage rigidity appeared to be a late complication of the disease The relation between the degree of the scoliotic curve and the pulmonary impairment was studied by Mankin et al (1964) who found that the greater the curvature the greater was the deficit of the VC The observations made in the present study that the VC and the MVV in scoliotic patients were lower than expected normal values are in agreement with earlier observations

As pointed out by Hepper et al (1965) and Bjure et al (1968) the predicted normal estimates for spirometric values based on body height are falsely low in scoliosis This tends to hide the decrease in VC and MVV caused by scoliosis when expressed as a percentage of the normal values By correcting body height for the scoliosis angle, according to Bjure et al (1968), the deviation of the lung function of scoliotic patients from normal values is shown more accurately (Tables 2 and 3) However, this correction does not appreciably affect the results of the evaluation of the effect of the Milwaukee brace on lung function

One of the advantages of the Milwaukee brace compared with other methods of conservative treatment, preoperative correction, or postoperative support of the curved scoliotic spine, is supposed to be its lack of affect on the distensibility of the chest cage and hence the ventilatory capacity of the lungs The present study of 29 patients examined without the Milwaukee brace and soon afterwards with the brace applied showed that the Milwaukee brace *per se* does not appreciably influence the VC of the patients whereas the observed slight decrease of MVV was statistically significant

In the report by Gucker (1962) preoperative correction of the scoliotic deformity by means of a Milwaukee brace for 6 weeks or more resulted in a slight increase of the vital capacity in three out of five patients with paralytic scoliosis In the present series of mainly idiopathic scolioses no significant changes in VC or MVV were observed in 16 patients treated with the Milwaukee brace for a mean period of 15 months (Table 3) Contrary to the effect of casts used previously, reported by Gucker to reduce the VC up to one third, treatment with the Milwaukee brace does not decrease the VC or MVV appreciably

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Acta orthop scand 47, 546–548, 1976

TRAUMATIC HIP DISLOCATION IN CHILDHOOD

A Report of Three Cases

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Three cases of traumatic dislocation of the hip joint in children are *presented All were subjected to immediate closed reduction under* general anesthesia followed by immobilization by means of skin traction for 2 weeks Weight bearing was resumed 2–3 weeks after the injury, and at follow up examinations 23 to 27 months later the hip joints were found to be normal both clinically and radiographically

Key words hip dislocation, children

Accepted 19 viii 76

Traumatic dislocation of the hip joint is an uncommon injury in children, and *there is no general agreement in the literature* as to the treatment and prognosis of these patients During a period of 5 weeks three children with this injury were seen at Akershus Central Hospital, and this paper relates our experience with them

CASE REPORTS

Case 1 H H a 4 year old boy fell off while riding a toboggan He arrived at the hospital *within an hour of the accident His left hip was* flexed and adducted and the greater trochanter was displaced posteriorly Attempts to move the leg were painful *X rays confirmed the diagnosis* of posterior dislocation no fractures were seen Reduction under general anesthesia was accomplished easily and successfully as confirmed by X-rays Skin traction was applied for 15 days then mobilization without weight bearing was allowed The intention was to postpone weight bearing for 3 months However once free of the traction apparatus, the patient resumed full activity including weight bearing This seemed to have no adverse effects and 27 months after the injury the hip was completely normal both clinically and radiographically

Case 2 I S, a 5 year old girl *sustained an* injury to the left hip while skiing She arrived at the hospital 9 hours later, her left hip in flexion and adduction X-rays showed a posterior dislocation of the hip joint but no associated fracture The dislocation was reduced under general anesthesia, and skin traction was applied for 15 days As with the first patient we tried to prevent weight bearing for a period of time but without success The course was how



Figure 1 Frontal radiograph (Case 3) showing posterior dislocation of the left hip No fractures are seen



Figure 2 Frontal view of the same patient as in Figure 1 showing a normal left hip immediately after closed reduction

ever uneventful and at follow up 24 months later the hip was normal

Case 3 B S G a 3 year-old girl Her left hip was crushed beneath a slab of rock while she was playing On admission to the hospital 2 *hours later she had both clinically and radiographically* (Figure 1) a posterior dislocation of her left hip No fracture was seen Immediate closed reduction was performed under general anesthesia (Figure 2) and skin traction applied for 12 days As with the other patients weight bearing could not be prevented for very



Figure 4 Lateral view of the same hip

long, and normal activities were resumed after approximately 3 weeks At follow up 23 months later the hip showed a full range of painless movement there was no shortening of the extremity and the radiographs were completely normal (Figures 3 and 4)



Figure 3 The same patient at follow-up examination 23 months after the injury Frontal view shows a completely normal left hip

DISCUSSION

Traumatic dislocation of the hip in children is a rare injury, and no single author has experienced sufficient cases to draw valid conclusions regarding treatment and prognosis A larger number of patients, however, have been collected from various institutions and reviewed (Epstein 1973, Funk 1962 Glass & Powell 1961, Pearson & Mann 1973, Pennsylvania Orthopaedic Society 1968) The results of these investigations give certain guidelines for treatment

There is general agreement that early reduction, i e , within 24 hours, is of utmost importance in preventing sequelae Closed reduction of uncomplicated, fresh dislocations is almost always possible, leaving open reduction for only a small proportion of the neglected cases and the otherwise exceedingly rare irreducible fresh ones

There is however, little agreement as to the post reduction treatment Most surgeons have used some sort of immobilization lasting from a few days to

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Figure 1 Frontal radiograph (Case 3) showing posterior dislocation of the left hip No fractures are seen

Acta orthop scand 47 549-557, 1976

THROMBOSIS FOLLOWING HIP ARTHROPLASTY

A Study Using Phlebography and ¹²⁵I-Fibrinogen Test

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Department of Orthopaedic Surgery and Diagnostic Radiology, University Hospital, Uppsala Sweden

Venous thrombosis after hip arthroplasty was studied using the ^{125}I fibrinogen test and phlebography Eight out of ten dextran treated and six out of ten control patients developed thrombosis The thrombi were small and most frequently dorsal and dorso lateral veins were involved There were no thigh thrombi without concurrent calf thrombi Half of the thrombi were found within the first postoperative week whereas the remainder occurred later Preoperative venous pathology predisposed to postoperative thrombosis

Key words arthroplasty fibrinogen test phlebography thrombophlebitis

Accepted 12 viii 76

Becker & Schampi (1973) and Bergqvist et al (1973) found, in a study of postoperative venous thrombosis, a diagnostic discrepancy between the ^{125}I-fibrinogen test and phlebography in patients treated with dextran 70 It was suggested that this was due to a faster lysis of thrombi in dextran treated patients These results together with studies showing an altered fibrin structure after dextran treatment (Tangen et al 1972) raise the question of whether thrombi formed in dextran-treated patients are lysed more easily than in other patients Our investigation of patients operated on for hip arthrosis was made to study the frequency, localization and natural history of thrombosis and to analyse the occurrence of thrombolysis after dextran treatment

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MATERIAL

Patients between 45 and 70 years of age with hip arthrosis were included in the study The operation was carried out via a lateral incision and without trochanteric osteotomy The Charnley prosthesis was used in all cases and vacuum drainage was applied for 2–3 days postoperatively Extra-dural analgesia was used in all cases The legs were kept in abduction postoperatively and the operated leg was prevented from outward rotation by a bar applied to a dorsal plaster of the lower leg The patients were instructed to do isometric muscle contractions as soon as they came to the intensive care unit The day after the operation exercises under the supervision of a physiotherapist were begun The patients left the hospital within 4 weeks

The patients were randomized into two groups, 10 control patients without prophylaxis and 10 patients given dextran 70 (Macrodex 6 per cent in saline Pharmacia AB Uppsala Sweden) One dextran infusion was given during the operation, one in the first postoperative hour and one on each of postoperative days 1, 3 and 5 The infusion dose was body weight-dependent, thus patients below 60 kg were given 400 ml patients between 60 and 80 kg 500 ml and patients above 80 kg 750 ml on each occasion The first dextran

about 2 months This has been achieved by traction, spica cast or bed-rest alone We used skin traction for 12–15 days in our patients It was well tolerated and seemed to be adequate

It is more difficult to assess the importance of the non-weight-bearing period Recommendations regarding duration of this period differ from a few days (Hovelius 1974) or until the hip is painless (Pearson & Mann 1973), to 3 months (Freeman 1961, Funk 1962) A correlation between the period of non-weight-bearing and the frequency of avascular necrosis of the femoral head has been proposed (Funk 1962), but according to other authors there is no such correlation (Piggot 1961, Epstein 1973) Our patients were immobilized for 2 weeks and started weight-bearing on their own after 2–3 weeks in spite of our intention to avoid weight-bearing for another 2–3 months It is also the experience of others that these children cannot be kept from starting their normal activities once the protective device is removed (Pearson & Mann 1973) This probably indicates that already the synovial irritation has subsided None of our patients has developed avascular necrosis or other sequelae

According to the literature, there seems to be a distinct age variation with regard to post-traumatic avascular necrosis This complication is almost unknown in children under 6 years of age, while in older children the frequency is about 10 per cent (Piggot 1961, Pennsylvania Orthopaedic Society 1968) This could partly be explained by the findings of Trueta (1957), studying the vascular anatomy of the femoral head during growth He was able to show that the vessels of the ligamentum teres do not contribute to the nourishment of the femoral head during the first 3 or 4 years, and that these vessels do not reach their full importance until after 8 or 9 years of age Our patients were in the younger age group, thereby supporting the evidence that these children have an excellent prognosis

Our patients were observed for a minimum of 23 months after the injury There is still some disagreement as to when the final outcome can be evaluated There are, however, only two cases reported in the literature where the diagnosis of avascular necrosis was made later than 23 months after the injury (Haliburton et al 1961, Pearson & Mann 1973), and one of these was a neglected case where the reduction took place a week after the dislocation The final prognosis should nevertheless be reserved until skeletal maturity is reached (Pennsylvania Orthopaedic Society 1968)

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Acta orthop scand 47, 549–557, 1976

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A Study Using Phlebography and ¹²⁵I-Fibrinogen Test

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Key words arthroplasty, fibrinogen test, phlebography, thrombophlebitis

Accepted 12 viii 76

Becker & Schampi (1973) and Bergquist *et al* (1973) found, in a study of postoperative venous thrombosis, a diagnostic discrepancy between the ^{125}I-fibrinogen test and phlebography *in patients treated with dextran 70* It was suggested that *this was due to a faster lysis of thrombi in dext*

(Langen *et al* 1972) raise the question of whether *thrombi* formed in dextran-treated patients are lysed more easily *than in* other patients Our investigation of patients operated on for hip arthrosis was made *to study the* frequency, localization *and natural* history of thrombosis and *to analyse* the occurrence of thrombolysis after dextran treatment

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MATERIAL

Patients between 45 and 70 years of age with hip arthrosis were included in the study The operation was carried out via a lateral incision and without trochanteric osteotomy The *Charnley* prosthesis was used in all cases and *vacuum* drainage was applied for 2–3 days postoperatively Extra-dural analgesia was used in all cases *The legs* were kept in abduction postoperatively *and the* operated leg was prevented from outward rotation by a bar applied to a *dorsal* plaster of the lower leg The patients *were instructed* to do isometric muscle contractions *as* soon as they came to the intensive care unit The *day after* the operation exercises under the *supervision of a* physiotherapist were begun The patients left the hospital within 4 weeks

The patients were randomized into two *groups, 10* control patients without prophylaxis and 10 *patients* given dextran 70 (Macrodex 6 per cent in saline, Pharmacia AB, Uppsala, Sweden) One *dextran* infusion was given during the operation, *one in* the first postoperative hour and one on each of postoperative days 1, 3 and 5 The infusion dose was body-weight-*dependent*, thus pat[illegible]

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about 2 months This has been achieved by traction, spica cast or bed-rest alone We used skin traction for 12–15 days in our patients It was well tolerated and seemed to be adequate

It is more difficult to assess the importance of the non-weight-bearing period Recommendations regarding duration of this period differ from a few days (Hovelius 1974) or until the hip is painless (Pearson & Mann 1973), to 3 months (Freeman 1961, Funk 1962) A correlation between the period of non-weight-bearing and the frequency of avascular necrosis of the femoral head has been proposed (Funk 1962), but according to other authors there is no such correlation (Piggot 1961, Epstein 1973) Our patients were immobilized for 2 weeks and started weight-bearing on their own after 2–3 weeks in spite of our intention to avoid weight-bearing for another 2–3 months It is also the experience of others that these children cannot be kept from starting their normal activities once the protective device is removed (Pearson & Mann 1973) This probably indicates that already the synovial irritation has subsided None of our patients has developed avascular necrosis or other sequelae

According to the literature, there seems to be a distinct age variation with regard to post-traumatic avascular necrosis This complication is almost unknown in children under 6 years of age while in older children the frequency is about 10 per cent (Piggot 1961 Pennsylvania Orthopaedic Society 1968) This could partly be explained by the findings of Trueta (1957), studying the vascular anatomy of the femoral head during growth He was able to show that the vessels of the ligamentum teres do not contribute to the nourishment of the femoral head during the first 3 or 4 years, and that these vessels do not reach their full importance until after 8 or 9 years of age Our patients were in the younger age group, thereby supporting the evidence that these children have an excellent prognosis

Our patients were observed for a minimum of 23 months after the injury There is still some disagreement as to when the final outcome can be evaluated There are, however, only two cases reported in the literature where the diagnosis of avascular necrosis was made later than 23 months after the injury (Haliburton et al 1961, Pearson & Mann 1973), and one of these was a neglected case where the reduction took place a week after the dislocation The final prognosis should nevertheless be reserved until skeletal maturity is reached (Pennsylvania Orthopaedic Society 1968)

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Table 1 Preoperative pathological venous systems as revealed by the preoperative phlebography

	No of legs with		
	varicose veins	pre operative thrombosis	venectasies
Control group	3	2	0
Dextran group	6	1	1

tween the control and test groups The results of preoperative phlebography are shown in Table 1 Thus, three patients had deep vein thrombosis already before operation One of them had been operated on with hip replacement on the same leg 6 months earlier and two had been operated on for other reasons several years earlier However none of them had a positive fibrinogen test indicating an active thrombosis

In three of the legs there was an increased fibrinogen uptake on the preoperative scans a 'primary pathological pattern", but none of these legs were pathological according to the preoperative phlebographs In one of these legs a postoperative thrombosis developed, verified by phlebography

A summary of the patients developing thrombosis is shown in Table 2 Phlebography showed postoperative thrombosis or propagation of preoperative thrombosis in 16 legs of 12 patients Eight patients belonged to the dextran group and four to the control group

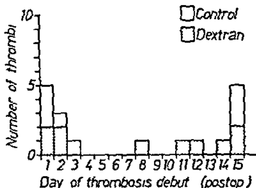


Figure 2 The day of thrombosis debut

Postoperative thrombosis was diagnosed with either the ¹²⁵I fibrinogen test or phlebography or both in altogether 18 legs of 16 patients eight patients belonging to the dextran group and six to the control group In eight patients the thrombi were localized only to the operated leg, in four cases localized to both legs and in two cases to the non operated leg (one with venectasies and the other with a preoperative thrombosis) Nine thrombi were found in the 13 legs with a preoperative pathological phlebogram In all three legs with a preoperative thrombosis, progress was seen postoperatively In only two legs was thrombosis suspected clinically

One patient (no 7 in Table 2) with bilateral thrombosis died and autopsy showed fatal pulmonary embolism This patient was one of the three with thrombosis of the femoral vein

In Figure 1 the localization of thrombi according to the ¹²⁵I fibrinogen test is shown In three patients (nos 7, 11 and 14 in Table 2) there were phlebographical thrombi in the femoral vein which were not detected by the fibrinogen test, but these patients also had thrombi in the

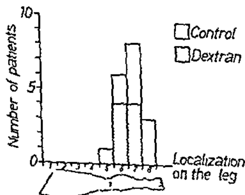


Figure 1 The localization of thrombosis according to the ¹²⁵I fibrinogen test

infusion was started as soon as the extra dural injection had been given

DIAGNOSTIC METHODS AND EVALUATION

^{125}I-fibrinogen test

The method originally described by *Atkins & Hawkins* (1965) was used For details see Bergquist et al (1973) The legs were scanned preoperatively, immediately postoperatively and every postoperative day for at least 1 week An increase in radioactive uptake relative to the heart of 15 per cent or more between two consecutive points was used as a diagnostic criterion of thrombosis This increase had to be present for two or more consecutive examinations We have earlier found this to be reliable in comparison with phlebography (Bergquist et al 1973) Patients with their first uptake increase on day 7 were also scanned on day 8 If thrombosis was diagnosed the investigation was continued for a fortnight and in some cases a re injection of ^{125}I labelled fibrinogen was necessary The preoperative leg scans were analysed for the presence of primary pathological pattern (Becker 1972)

Phlebography

The method of examination was standardized and in certain respects slightly modified in comparison with phlebographic techniques described by other authors (Greitz 1954 1955 Gullmo 1956 Nylander 1962 Bronge et al 1971)

A Siregraph (Siemens) with remote control and TV fluoroscopic monitor was used The patient was kept in position with the aid of a broad compression bandage across the trunk The edges of the table were supplied with handles for the patient s support and to facilitate muscular relaxation in the examined leg The adjustable table was elevated to an angle of about 65° with the horizontal plane The examined leg was positioned in inward rotation (20–30°) A superficial vein on the dorsum of the foot was punctured and no tourniquet was applied Manual injection of 80 ml 45 per cent Urografin (Schering) was started and film exposures in the antero posterior projection were made after the injection of about 40 ml of contrast medium Films were taken over the lower leg, knee region, thigh and pelvic region and then in the lateral projection after an additional injection of 60 ml of contrast medium Fluoroscopic monitoring was especially useful when taking pictures of the femoral and external iliac veins In certain cases complementary films were taken after a further injection of contrast medium In some patients a tourniquet was applied above the ankle joint to reduce the superficial circulation and to improve the deep venous filling A bilateral control phlebography was made within the week before operation to show post thrombotic states, preoperative thromb varicose veins and variations in the venous anatomy If the ^{125}I fibrinogen test was positive bilateral phlebography was performed on days 5–7 after operation In patients with thrombosis an additional bilateral phlebography was performed on day 14 and all patients were given a bilateral phlebography around day 21 The radiologist was not informed whether the patient belonged to the control or dextran group

Thrombosis was regarded as present if the examination showed

1 A contrast defect in a venous lumen ending in a cranially convex contour
2 Occlusion of one of the two parallel veins between two communicants in any of the three main trunks of the lower leg
3 Occlusion of a vein with a demonstrable collateral circulation
4 Defective filling of a deep vein despite repeated injection of contrast medium
5 Total lack of filling of the deep crural veins with increased flow in the superficial veins

In this investigation there was no instance of subfascial soft tissue pressure, raised to a level above the venous pressure giving the findings described under 5

These phlebographic criteria of acute and subacute thrombosis are those most generally accepted (Bauer 1940, Nylander 1962 1968, Hjelmstedt & Bergvall 1968 May & Nissl 1973)

Phlebography performed as described above is a reliable method but often gives incomplete filling of muscular veins and of the deep femoral vein The deep femoral vein was visualized in 25 per cent of the phlebographies Small thrombi in the superficial veins are probably often not discovered on phlebograms No special attempts were made to increase the filling of the muscular veins by muscular contractions or pneumatic cuffs (Almén & Nylander 1962 Nicolaides et al 1971)

A total of 106 phlebographies was performed on the 40 legs of the 20 patients One patient had an allergic reaction with widespread urticaria and erythema at the preoperative phlebography as a result of which he was excluded from the trial and replaced by another patient There were no further complications except for some mild orthostatic reactions

RESULTS

There was no difference in age (mean 67 and 63 years, respectively) or sex be-

Table 3 The site of the thrombi according to the phlebographic findings in 12 of the 20 patients

	Operated leg	Non operated leg	Total
Superficial veins of the lower leg	2	1	3
Fibular veins	9 *	5 *	14
Posterior tibial veins	3	1	4
Soleal veins	3	3 *	6
Anterior tibial veins	–		–
Popliteal veins	2	–	2
Superficial femoral veins	3	–	3
Total	22	10	32

Six patients had thrombi only in the operated leg, two only in the non-operated leg and four bilateral (totally 16 legs) According to Williams (1953) the veins from the soleus usually join the fibular veins

* indicates propagation of an earlier preoperatively visualized thrombus

calf There was no case of positive uptake above the knee

In Table 3 the localization of thrombi according to phlebography is shown Several separate thrombi often occurred in the same leg The thrombi of the femoral veins as well as one of the two popliteal thrombi had no connection with concurrent thrombi of the calf Of the 12 patients with visualized thrombi on the phlebograms in six the thrombi were rather small in one the thrombus propagated to the popliteal vein and in three there was small to moderate non occluding thrombi in the femoral veins

In Figure 2 the day for thrombosis [illegible] test were not detected until more than 1 week postoperatively Six of the thrombi in the dextran group and three in the control group appeared after 1 week

An estimate of the development of thrombosis was made by a combined analysis of leg scans and phlebograms There was progress in three of the dextran treated patients and in one from the control group Regression was seen in one control patient (no 14 in Table 2) (Figure 3)

DISCUSSION

This study does not indicate the occurrence of faster lysis of thrombi in dextran treated patients Phlebographically partial lysis could only be demonstrated in one patient belonging to the control group (Figure 3)

There was no difference in the frequency of thrombosis between the dextran and control groups However, no definite conclusion regarding the prophylactic effect of dextran can be made as the series is small In hip surgery a reduction of the frequency of thrombosis after dextran prophylaxis has been found by Ahlberg et al (1968), Johnson et al (1968), Myhre & Holen (1969), and Evarts & Feil (1971), whereas Daniel et al (1972) found dextran to have no effect The prophylactic effect of dextran on fatal pulmonary embolism is well documented (Bygdeman et al 1970, Kline et al 1975)

There is a tendency for delayed thrombosis debut in dextran treated patients which has also been pointed out by Bergqvist & Dahlgren (1973) and was also the case in patients treated with low dose heparin (Hampson et al 1974) Within the first week after operation only half of the thrombi have appeared and it can be concluded that the true thrombosis frequency is only obtained if the patient is followed for a considerable time postoperatively

The frequency of thrombosis found here is in agreement with other materials with the same type of patients (Tillberg 1974, Hampson et al 1974, Morris et al 1974) The frequency of primary pathological pattern with leg scan is comparable with that of Becker (1972) and Bergman et al (1975)

The fibrinogen test and phlebography

Table 2 Summary of patients in whom diagnostic methods have given positive results

Group	Patient	125I-fibrinogen test	Point	Phlebography	Comments	Operation side
Dextran	1 right			Fib V day 23	Varicose veins	right
	left				Varicose veins	
Dextran	2 right	positive day 1–13	6, 7	SV, Fib V, PTV days 6, 14, 25	PPP progress	right
	left					
Dextran	3 right	positive day 2–7	5	Fib V, PTV days 7, 14		right
	left					
Dextran	4 right	positive day 14–18	6, 7	SV, PTV days 11, 18, 25	Clinical thrombosis	
	left	positive day 14–18	6	SV days 18, 25		left
Dextran	5 right			SV, Po V day 12	Preop DVT in Fib V	right
	left					
Dextran	6 right					right
	left	positive day 8–13	6	Gastr V days 11, 20	Preop venectasies	
Dextran	7 right	positive day 1–9	7	Fib V, FV day 7	Varicose veins	right
	left	positive day 2 6	7	SV day 7	Varicose veins Fatal pulm emb	
Dextran	8 right			Fib V day 25		right
	left					
Control	9 right			Fib V day 20	Clinical thrombosis	right
	left			Fib V day 25		
Control	10 right			Fib V, PTV day 25	Preop DVT Hip replacement	
	left					left
Control	11 right	positive day 1 4	7	SV, Fib V, FV days 5, 25	Varicose veins	right
	left	positive day 1–4	6–8	SV, Fib V days 5, 25	Preop DVT in Gastr V	
Control	12 right					
	left	positive day 1–2	7, 8		Varicose veins	left
Control	13 right					
	left	positive day 2–6	7, 8		Varicose veins	left
Control	14 right	positive day 3–5	6	SV, Fib V, FV days 7, 14, 21	Regression	right
	left					

Point' in the fibrinogen test column refers to the location on the leg of the thrombosis (see Figure 1) PTV = posterior tibial vein, Fib V = fibular vein, SV = soleal veins, Po V = popliteal vein, Gastr V = gastrocnemic veins, FV = femoral vein PPP = primary pathological pattern DVT = deep venous thrombosis

localize and visualize the thrombi at an early stage of their development and thus determine the area most prone to initiate the thrombotic process The most common sites of thrombosis have been found to follow this order the fibular veins the muscle veins of the calf the posterior tib al veins and a few in the distal part of the venous veins of the lower leg There were no thrombi in the anterior tibial veins

In the three cases with thrombosis of the femoral vein there was no connection between this and the concurrent thrombi in the lower leg In these cases the fibrinogen test had shown calf vein thrombosis before phlebography showed a thrombus in the femoral vein In our material we have no case of isolated thrombi above the knee level Thus in most cases thrombi seem to be formed in the dorsal and dorso-lateral venous system of the lower leg and in a few cases concurrently in the thigh veins

As the thrombi are formed far from the field of operation or in the contra lateral leg it seems likely that endothelial lesions are caused mechanically by compression of the veins during the operation and during the inactivity afterwards (Frimann Dahl 1947 Robertson et al 1959) Compression may also cause hypoxia of the endothelial cells The veins most commonly occupied by thrombi are also those having the lowest blood flow (Nicolaides et al 1972)

This compression hypothesis has been well formulated by Frykholm (1940)

t have also been demonstrated experimentally by Samuels & Webster (1952) and Stehbens (1965) It seems probable that there must be a combination of endothelial lesion and stasis to form a thrombus (Wessler & Stehbens 1971) As our study supports the compression hypothesis one important prophylactic measure would be to diminish long lasting compression This could be done by putting the leg on a support distributing the pressure over a larger area Another method known to have a prophylactic effect is calf muscle stimulation (Browse & Negus 1970 Becker 1972) Administration of dextran improves blood flow

No single prophylactic measure is able to abolish thrombosis and probably a combination of various procedures with different modes of action is the way out of the problem Dicumarol and heparin given in the traditional dosage can lead to severe postoperative bleeding and are thus not suited to hip surgery The effect of low dose heparin in hip surgery is under debate (Hampson et al 1974 Morris et al 1974) The prophylactic value of a combination of calf muscle stimulation and dextran infusion is worth investigating

Conclusions

1 This study has not shown dextran to have any effect
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halt after more than 1 week
3 Local compression of the veins in combination with inactivity during and after operation are important factors in thrombogenesis
4 Preoperative phlebography is valuable as it reveals anatomical variations and venous pathology
5 Legs with preoperative venous pathology are more prone to develop post operative thrombosis than are non diseased legs

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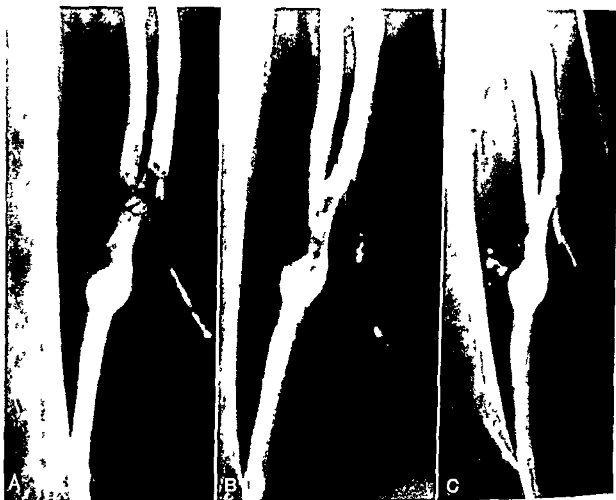


Figure 3 A case of spontaneous regression of deep venous thrombosis The patient was not treated with any drugs

A *In the middle part of the right thigh there is a thrombosis about 5 cm in length in the femoral vein and its branch This phlebography was performed on the seventh postoperative day The preoperative phlebogram was normal*

B *Two weeks postoperatively there is a minor regression of the thrombosis*

C *Three weeks postoperatively the third phlebography was performed showing a pronounced regression of the thrombosis*

do complement each other diagnostically, phlebography being more reliable in the proximal part of the extremity and the fibrinogen test in the distal The fibrinogen test is well suited for detection of early and also rapidly disappearing thrombi while phlebography can be also used for detection of late thrombi and post-thrombotic states A preoperative pathological venous system indicated in the phlebograms predisposes to postoperative thrombosis, a development not seen by Becker et al (1970)

As already postulated by Virchow (1856) an endothelial lesion is one prerequisite for venous thrombosis, the others being altered blood and flow characteristics By studying where in the venous system the primary thrombi are formed, it is possible to tell where the thrombotic process starts The thrombus must, however, have a length of a few centimeters to be detectable, the fibrinogen test being the more sensitive In addition, it is mainly thrombi in the venous trunks which can be diagnosed by phlebography

In this study it has been possible to

localize and visualize the thrombi at an early stage of their development and thus determine the area most prone to initiate the thrombotic process The most common sites of thrombosis have been found to follow this order the fibular veins, the muscle veins of the calf, the posterior tibial veins and a few in the distal part of the venous veins of the lower leg There were no thrombi in the anterior tibial veins

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This compression hypothesis has been well formulated by Frykholm (1940) based on autopsy studies, but was already postulated by Virchow (1856) Endo thelial lesions in the formation of throm bi have also been demonstrated experi mentally by Samuels & Webster (1952) and Stehbens (1965) It seems probable that there must be a combination of endothelial lesion and stasis to form a thrombus (Wessler & Stehbens 1971) As our study supports the compression hypothesis one important prophylactic measure would be to diminish long lasting compression This could be done by putting the leg on a support distributing the pressure over a larger area Another method, known to have a prophylactic effect, is calf muscle stimulation (Browse & Negus 1970, Becker 1972) Administration of dextran improves blood flow

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Acta orthop scand 47, 558-565, 1976

EXPERIMENTAL OSTEOARTHRITIS IN THE RABBIT KNEE JOINT

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The development of arthrotic like changes following resection of the cruciate ligaments in the knee joint of rabbits has been studied at intervals from 2 weeks to 10 months in 35 animals Signs of cartilage degeneration were followed by changes in the subchondral bone where formation of osteophytes and condensation took place An increased vascular supply was demonstrated by microangiographic and scintigraphic investigations The uptake of ^{18}F and ^{99m}Tc polyphosphate reached a maximal value about 2 months after the operation and then diminished despite further development of arthrotic changes

Key words osteoarthritis, cartilage, subchondral bone osteophytes scintigraphy, blood flow

Accepted 23 vi 76

In osteoarthritis, changes in blood circulation take place which may help to understand the processes involved Thus the important part played by hypervascularization of the subchondral bone has been demonstrated by microangiographic investigations (Harrison et al 1953) and scintigraphic results support the contention that the blood supply to the diseased joint is increased (Danielsson et al 1963, Jeremy et al 1969, Muheim & Crutchlow 1971) The presence of delayed venous outflow in osteoarthritis has been demonstrated by various methods (Ficat & Arlet 1975, Phillips 1966, Hernborg 1969, Arnoldi et al 1972) Animal experiments have shown that venous obstruction results in an increased density of the subchondral bone (Brookes & Helal 1968, Lilly & Kelly 1970), and thus may initiate arthrotic changes On the other hand, it is the general opinion that changes in the subchondral bone are secondary to degenerative processes in the joint cartilage which seem to give rise to an increased blood supply (Collins 1949, Sokoloff 1969, Freeman 1972)

In the present investigation the development of arthrotic-like changes, induced experimentally in the knee joint of rabbits, has been followed, with special attention being paid to the vascular reaction

MATERIALS AND METHODS

Thirty six adult male white rabbits weighing about 4 kg were submitted to an operation on the right knee using a modification of the method of Hulth et al (1970) Under strictly sterile conditions the knee joint was opened by transection of the medial collateral ligament The medial meniscus was removed *in toto* and both lig cruciata resected The joint was then unstable and in order not to provoke sub

luxation the medial collateral ligament was re sutured with plain catcut No 4-0 Stability was further ensured by suturing of the fascia and the skin was closed with atraumatic Nylon The operation was performed under *Nembutal* anesthesia In five animals serving as controls the same operation was performed including removal of the medial meniscus, but the lig cruciata were left intact The animals recovered *soon after the operation and in the course of a* few days were able to move freely about the cage One had to be excluded from the study because of destructive inflammation of the joint but otherwise no infection occurred Two *animals died of intercurrent* diseases

The rabbits were sacrificed at intervals be ginning at 2 weeks and extending to 10 months From both knee joints the medial and lateral condyles of the femur and tibia were isolated and *the patella removed* thus obtaining five different samples from each joint After fixation in formalin and dehydration in alcohol most specimens were embedded in methylmethacry late but some were decalcified in formic acid followed by embedding in paraffin Microradio graphic investigation was performed on 100 μ thick specimens obtained by cutting with a saw and grinding A Machlett O I G 50 X ray tube with Wolfram anode was used for contact exposures on Kodak Spectroscopic film 649-0

Sections of 8 μ thickness were obtained from both decalcified and undecalcified specimens with a Jung microtome and stained with toluidine blue haematoxylin and eosin and soluchrome *In seven instances a microangiographic* investigation was made according to the method of Trueta & Harrison (1953) with perfusion of 25 per cent micropaque through the abdominal aorta in the anaesthetized animal just prior to *sacrifice Tetracycline labelling was performed* in a few animals using two i m injections (with an interval of 1 week) of 150 mg Reverin (Pyr rolidinomethyl tetracyclin) before sacrificing

Scanning with radioactive fluoride (^{18}F) or *technicium labelled polyphosphate* (^{99m}Tc PP) was done in all animals one or several times postoperatively using a 5 inch Fiscint whole body rectilinear scanner with videodisplay and processing for quantitative measurements Con *tact autoradiographies were obtained by placing* ½ mm thick sections on Kodak film P E 4006 using an ultrathin P W membrane between section and film

The histological description includes the joint cartilage *the layer of calcified cartilage and the* subchondral bone Metachromasia was evaluated on toluidine blue stained sections in degrees from 3–0 ... her 3 ...

Table 1 Macroscopic and histologic findings on the medial femoral condyle

Animal n	Time after op	m chr	Joint cartilage: thickness (μ)	cls frm	fbr lat	erosion	Calcified cartilage: thickness (μ)	perfor	Subchondral bone: end plate (μ)	osteoid	osteophyte	Collins* (degree)
259	2 w	3	200	0	0	0	120	10	400	0	0	0
240	3 w	2	350	0	0	0	80	8	400	0	0	1
260	1½ m	1	200	++	++	0	50	8	150	+	+	2
261	2 m	1	200	+	+	+	100	10	300	++	0	2
258	3 m	2	300	+	+	+	120	11	500	+	+	3
249	4 m	2	500	+	+	+	100	10	450	+	+	3
255	5 m	2	300	+	+	++	100	10	1000	++	++	3
251	6 m	2	400	+	+	++	100	8	300	+	+	3
257	7 m	1	300	+	+	++	200	10	1500	++	+	3
236	8 m	1	600	+	+	++	300	11	600	±	±	3
266	9 m	0	400	++	++	+++			600	+	+	4
244	10 m	2	400	+	+	+	125	6	700	+	+	3

* Collins (1949)
m chr — metachromatic staining ability (see text)
cls frm — cluster formation of cartilage cells
fbr lat = fibrillation
perfor — vessels *perforation into the calcified* cartilage from the subchondral bone (number per mm)

Acta orthop scand 47, 558–565, 1976

EXPERIMENTAL OSTEOARTHRITIS IN THE RABBIT KNEE JOINT

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The development of arthrotic like changes following resection of the cruciate ligaments in the knee joint of rabbits has been studied at intervals from 2 weeks to 10 months in 35 animals Signs of cartilage degeneration were followed by changes in the subchondral bone where formation of osteophytes and condensation took place An increased vascular supply was demonstrated by microangiographic and scintigraphic investigations The uptake of ^{18}F and ^{99m}Tc polyphosphate reached a maximal value about 2 months after the operation and then diminished despite further development of arthrotic changes

Key words osteoarthritis, cartilage, subchondral bone osteophytes scintigraphy, blood flow

Accepted 23 vi 76

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In the present investigation the development of arthrotic like changes induced experimentally in the knee joint of rabbits has been followed with special attention being paid to the vascular reaction

MATERIALS AND METHODS

Thirty six adult male white rabbits weighing about 4 kg were submitted to an operation on the right knee using a modification of the method of Hulth et al (1970) Under strictly sterile conditions the knee joint was opened by transection of the medial collateral ligament The medial meniscus was removed *in toto* and both lig cruciata resected The joint was then unstable and in order not to provoke sub

Table 2 Quantitative histological evaluation of the specimen

Specimen		Joint cartilage		Calcified cartilage		Bone end plate thickness
		m chr	thickness	thickness	perf	
Med fem condyle	r (22)	1 7	*365 ± 126	121 ± 55	10	*618 ± 363
	l (19)	3	249 ± 67	103 ± 30	9	269 ± 67
Lat fem condyle	r (21)	2 3	*317 ± 117	114 ± 42	9	270 ± 134
	l (16)	3	215 ± 82	101 ± 32	11	210 ± 63
Med tib condyle	r (17)	2 0	664 ± 211	125 ± 65	11	530 ± 301
	l (18)	3	623 ± 206	86 ± 31	10	404 ± 101
Lat tib condyle	r (19)	2 4	362 ± 126	107 ± 38	13	289 ± 121
	l (16)	3	305 ± 106	90 ± 44	12	241 ± 122
Patella	r (15)	2 1	*481 ± 189	112 ± 33	15	318 ± 110
	l (13)	2 8	257 ± 92	92 ± 17	13	275 ± 107

r and l = right and left joint respectively the number of the specimen examined is given in brackets
m chr = metachromatic staining ability (see text)
Thickness of joint cartilage, calcified cartilage and subchondral end plate is given in microns
Perf signifies vessels perforating into the calcified cartilage from the subchondral bone (number per mm)
The values marked with * differ significantly from the control value ($P < 0.01$)

formation of osteophytes, first as exostoses along the edge of the cartilage, but later also in more central parts of the joint (Figure 2) The formation of osteophytes was associated with a vascular reaction, in which vessels from the subchondral bone penetrated the layer of calcified cartilage and initiated bone formation in the cartilage A new ossification front was established while the old one gradually disappeared leaving the bone and joint surface elevated (Figure 2) The presence of hyperaemia in the bone tissue was demonstrated on microangiographic pictures (Figure 3) and the amount of osteoid tissue as well as tetracycline labelling (Figure 4) indicated increased bone formation This ultimately resulted in sclerosis of the subchondral bone especially where the joint cartilage had been eroded with denudation of the bone

Changes similar to those described take place on the medial tibial condyle and to a lesser extent on the lateral femoral condyle while only slight changes were seen on the lateral tibial condyle On the patella, exostoses at the edge of the cartilage developed at an early stage in combination with a decrease in metachromatic staining and an increased thickness of the cartilage, which was more pronounced here than in other parts of the knee joint

The quantitative results of the histologic investigations are summarized in Table 2 where mean values (with standard deviations) of the measurements on each of the different joint surfaces are given and compared with the corresponding measurements in the normal knee joint It is seen that the thickness of the joint cartilage, on the average, increases somewhat on all joint surfaces, but the difference from the normal values is only statistically significant for the femoral condyles and the patella As regards the calcified cartilage an increased thickness is generally observed, but the variations are too great for any conclusions to be



Figure 1 Cartilage from femoral condyle showing loss of metachromasia in the superficial layer, slight fibrillation and formation of cell clusters (toluidine blue, × 100)

0 total absence of metachromasia Measurements of the thickness of the cartilage and subchondral bone were made with a micrometric eye piece The number of vessels (per mm) perforating the calcified cartilage from the subchondral bone was evaluated from the microradiographs From the macroscopic and histological findings the degree of arthrotic changes was allotted according to the grading of Collins (1949), where 0 signifies a smooth joint surface and 1–4 increasing degrees of cartilage degeneration and denudation of bone

RESULTS

At the dissection the operated knee joint appeared swollen but only in a few cases was the amount of synovial fluid increased The joint capsule was hypertrophic and along its attachment the bone was eroded The medial meniscus had been partly replaced, whereas recovery of the cruciate ligaments was not seen To the naked eye the cartilage surface appeared mostly dull, yellowish and often rough with signs of fibrillation At a later stage the cartilage was eroded leaving the denudated subchondral bone shiny and smooth This was especially seen on the top of the medial femoral condyle and in the centre of the medial tibial condyle The macroscopic and histologic changes in the knee joint following the operation varied for the different joint surfaces In Table 1 figures from the medial femoral condyle are given for a representative selection of animals arranged according to the time after operation It is seen that as early as 3 weeks after the operation there was some decrease in the metachromatic staining of the cartilage This was followed by further signs of degeneration including formation of cell clusters and fibrillation (Figure 1) At this stage an increased thickness of the calcified layer was sometimes observed with prolonged extensions into the subchondral bone About 1½ months after the operation changes appeared also in the subchondral bone with



Figure 2 Microradiograph of femoral condyle showing formation of osteophytes and vessels perforating the calcified cartilage (× 25)

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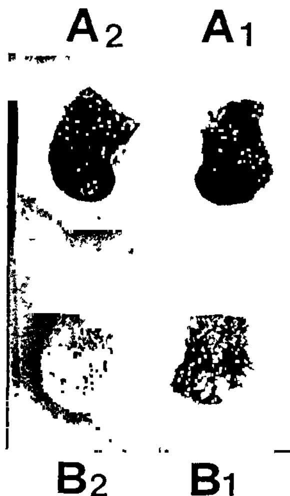


Figure 3 Microangiograph from the medial (A) and lateral (B) femoral condyles Comparison between right (1) and left (2) sides

ated and the normal knee joint is given as mean values with standard deviations It is seen that the uptake of both F 18 and Tc-PP increased on the operated side during the first 2 months after operation to reach a maximal value for the ratio of about 2 7 During the following months the ratio slowly decreased to about 1 6 at 9–10 months after the operation The uptake of F-18 differed only slightly from that of Tc-PP Autoradiographic investigations showed that the uptake in the early stages was primarily localized to the periphery of the joint At a later stage accumulations also took place in more central parts of the subchondral bone (Figure 6)

In the control animals, operated without resection of the cruciate ligaments drawn The number of vessels penetrating into the calcified cartilage from the subchondral bone did not differ from normal values, but the individual perforations were enlarged In the subchondral bone the thickness of the endplate increased on the average on all joint surfaces This was most distinct on the medial femoral condyle, where the difference from normal values was statistically significant, especially for specimens obtained more than 3 months after the operation

The results of the scintigraphic investigations with radioactive fluoride (F-18) and technicium polyphosphate (Tc-PP) are shown in Figure 5, where the ratio between the uptake in the oper-



Figure 4 Subchondral bone from femoral condyle Tetracycline labelling shows increased bone formation (unstained UV light × 100)

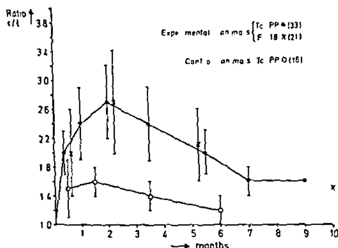


Figure 5 Results of scintigraphic measurements

only slight histological changes occurred corresponding to Collins' degrees of 0 1 The uptake of F-18 and Tc-PP although increased, was significantly less than in the experimental animals and the ratio declined to almost normal values during the course of about 6 months after the operation as seen in Figure 5

DISCUSSION AND CONCLUSIONS

From the present investigation it is seen that changes similar to those observed in human osteoarthritis take place in the knee joint of rabbits following resection of the cruciate ligaments This has previously been shown by Hulth et al (1970) and similar results have been obtained by other methods (Salter & Field 1960 Trias 1961, Thompson & Bassett 1970 Meachim 1963 Lemperg et al 1971 and Moscowitz et al 1973) In accordance with observations on human osteoarthritis, signs of cartilage degeneration preceded changes in the subchondral bone The increased ability for metachromatic staining is considered due to enzymatic degradation of mucopolysaccharides (Sokoloff 1969 Mankin & Lipiello 1970) The observed increase in thickness of the cartilage has also been described in human osteoarthritis (Meachim & Collins 1962) and seems due to proliferation of cartilage cells (Mankin et al 1971, Hulth et al 1972, Telhag 1972) In the subchondral bone changes are accom-

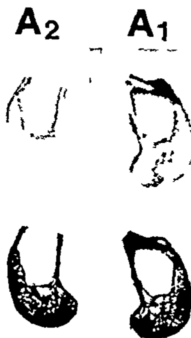


Figure 6 Autoradiograph above and radiograph below of femoral condyle Right (1) and left (2)

panied by an increased blood supply demonstrated especially as regards the formation of osteophytes (Harrison et al 1953) The uptake of F-18 and Tc-PP in the bone tissue, whether due to exchange processes or incorporation into apatite crystals, is generally considered to be primarily dependent upon the blood flow (Van Dyke et al 1965, French & McCready 1967, Wootton 1974 and McGrail et al 1974) From the scintigraphic results it therefore appears that the hyperaemia is connected with the development of arthrotic changes The fact that the uptake of radioactive indicators decreases somewhat, despite further progression of the arthrotic changes, indicates that hyperaemia is less involved in these later processes including condensation of the sub chondral bone (Danielsson et al 1963) Although it seems from the present investigation that the hyperaemia is secondary to the degenerative processes in the cartilage, it cannot be excluded, however, that hyperaemia may be a primary cause of osteoarthritis

ACKNOWLEDGEMENTS

My thanks are due to the Danish Rheumatic Association for financial support and to Mrs B Saugbjerg for technical assistance

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Figure 2 Ulceration of the cartilage through which the osteomyelitis drained into the joint (Case 1)

The synovial layer was closed and a subcutaneous drain was placed in the wound

Histology showed necrotic bone with granulation tissue Postoperatively antibiotics were given and a knee exercise program was started as soon as the wound had healed The post operative evolution was uneventful The signs of local inflammation subsided and knee function was regained

Follow up X ray examinations showed a further ossification of the patella (Figure 3)

Case 2

A 6 year-old boy complained of pain in the right knee especially at night There was no history of *trauma* There was a slight rise in temperature on admission 3 weeks after the onset of the complaints but no local signs of acute inflammation in the knee or prepatellar bursitis were *observed* The patella was very tender and knee flexion painful and restricted Biochemistry values were within normal limits X rays revealed an osteolytic zone with a sclerotic border in the proximal part of the patella (Figure 4) The diagnosis of low grade osteitis of the patella was made Conservative treatment with antibiotics and rest yielded an initial improvement for about a week There was however a recurrence of the complaints and the fever despite this treatment necessitating a surgical exploration The knee joint was not opened A sequestrum in the patella was removed

Histology demonstrated dead bone with chronic inflammation Culture of the tissue removed was negative The postoperative course was uneventful and normal knee function was regained

Case 3

A 5 year-old boy presented with a 3 month history of pain in the knee especially at night There was no history of trauma and no fever during the course of the disease The X rays 2 months after the onset of the complaints revealed an osteolytic zone with a sclerotic border and dense centre in the proximal patella Despite treatment with antibiotics the symptoms remained He developed tenderness and swelling on the patellar surface knee effusion and a pronounced quadriceps wasting *Knee* flexion was slightly restricted because of pain

Acta orthop scand 47, 566–569, 1976

HAEMATOGENOUS OSTEOMYELITIS OF THE PATELLA

Report of Three Cases

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Three cases of osteomyelitis of the patella are reported One presented as an acute septic arthritis and another developed a sterile arthritis despite antibiotics The clinical signs, diagnosis and treatment are discussed Treatment with rest and antibiotics failed to cure the disease In all three cases a sequestrectomy was carried out resulting in healing of the affected patella and recovery of knee mobility

Key words haematogenous osteomyelitis patella, septic arthritis sequestrectomy, antibiotics

Accepted 30 vi 76

Acute osteomyelitis of the patella is a very rare condition and is especially atypical under the age of five

In this paper three cases *of osteomyelitis of the patella* are reported The atypical course of the condition, the clinical signs and the treatment are discussed

CASE REPORTS

Case 1

A 3 year old girl developed a painful swollen knee and fever (38° C) Conservative treatment consisting of oral antibiotics was started and the affected leg was immobilized Several knee aspirations were carried out revealing an opaque fluid which remained sterile on culture but this was attributed to the antibiotic treatment Initial X rays of the knee were negative Repeat X-rays revealed only diffuse osteoporosis of the knee Because of the persistent picture of arthritis of the knee with high temperature despite antibiotics and the toxic symptoms the child was referred to our department

On admission, examination showed a warm swollen knee and synovial hypertrophy There was tenderness over the patella and a limited and painful flexion Tender glands in the groin were observed Sedrate was 152 after 1 hour WBC count was elevated to 16 000 and mild anaemia was present X rays now revealed necrosis with fragmentation and sequestration of the bony nucleus of the patella (Figure 1)

The diagnosis of osteomyelitis and secondary arthritis of the knee was made and an arthrotomy was carried out The synovial tissue was hyperaemic and hypertrophic The cartilage of the patella was ulcerated (Figure 2) A large sequestrum of the bony nucleus of the patella was removed and the knee joint was drained



Figure 1 Necrosis and sequestration of the bony nucleus of the patella (Case 1)



Figure 2 Ulceration of the cartilage through which the osteomyelitis drained into the joint (Case 1)

The synovial layer was closed and a subcutaneous drain was placed in the wound

Histology showed necrotic bone with granulation tissue Postoperatively antibiotics were given and a knee exercise program was started as soon as the wound had healed The postoperative evolution was uneventful The signs of local inflammation subsided and knee function was regained

Follow up X ray examinations showed a further ossification of the patella (Figure 3)

Case 2

A 6-year old boy complained of pain in the right knee especially at night There was no history of trauma There was a slight rise in temperature on admission 3 weeks after the onset of the complaints but no local signs of acute inflammation in the knee or prepatellar bursitis were observed The patella was very tender and knee flexion painful and restricted Biochemistry values were within normal limits X-rays revealed an osteolytic zone with a sclerotic border in the proximal part of the patella (Figure 4) The diagnosis of low grade osteitis of the patella was made Conservative treatment with antibiotics and rest yielded an initial improvement for about a week There was however a recurrence of the complaints and the fever despite this treatment necessitating a surgical exploration The knee joint was not opened A sequestrum in the patella was removed

Histology demonstrated dead bone with chronic inflammation Culture of the tissue removed was negative The postoperative course was uneventful and normal knee function was regained

Case 3

A 5 year-old boy presented with a 3 month history of pain in the knee, especially at night There was no history of trauma, and no fever during the course of the disease The X rays 2 months after the onset of the complaints revealed an osteolytic zone with a sclerotic border and dense centre in the proximal patella Despite treatment with antibiotics the symptoms remained He developed tenderness and swelling on the patellar surface knee effusion and a pronounced quadriceps wasting Knee flexion was slightly restricted because of pain

Acta orthop scand 47, 566–569, 1976

HAEMATOGENOUS OSTEOMYELITIS OF THE PATELLA

Report of Three Cases

J Vaninbroukx, M Martens, M Verhelst & J C Mulier

University Hospital Department of Orthopaedic Surgery, K U L, Pellenberg Belgium

Three cases of osteomyelitis of the patella are reported One presented as an acute septic arthritis and another developed a sterile arthritis despite antibiotics The clinical signs, diagnosis and treatment are discussed Treatment with rest and antibiotics failed to cure the disease In all three cases a sequestrectomy was carried out resulting in healing of the affected patella and recovery of knee mobility

Key words haematogenous osteomyelitis patella septic arthritis sequestrectomy, antibiotics

Accepted 30 xi 76

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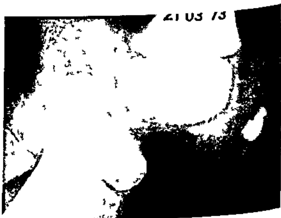


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Figure 3 Ossification after 9 months (Case 1)



Figure 4 Lateral view showing the osteolytic zone with sclerotic outline (Case 2)



Figure 5 A dense sequestrum with an osteolytic outline (Case 3)

Repeat X-rays after 2 weeks showed a slightly increased osteolytic zone with a dense sclerotic centre (Figure 5). Because the symptoms did not respond to conservative treatment with high doses of antibiotics an exploration was performed.

At surgery the bony nucleus of the patella was curetted from the upper surface leaving the cartilage intact. Histological examination revealed dead bone trabeculae and a lymphocytic and plasmocytic infiltration. The function of the knee was regained slowly as the signs of local inflammation regressed.

DISCUSSION

Most of the cases of osteomyelitis of the patella have been reported in children between the ages of 5 and 15. Moore (1938) suggested that this could be explained by the fact that before the age of five the patella is largely cartilaginous. The ages in our cases were 3, 5 and 6 years. In about half of the reported cases an injury is mentioned. In our first case there was a definite injury prior to the onset of the complaints.

An uncommon feature in one of the cases was the initial presentation as an arthritis of the knee joint. In case 3 a sterile reactional synovitis developed, case 2 at no stage presented an effusion. There is a thick layer of cartilage behind the ossifying focus of the patella, protecting the knee joint. On the other hand, the strong layer of fibres of the patellar

tendon covering the outer surface of the patella may represent an even stronger barrier for abscess formation to perforate and become more superficial In none of the three cases was prepatellar bursitis present, in contrast to Evans' report (1962) In case 1 although the outer cortex of the patella was perforated, the overlying fibres were not, so that drainage to the more superficial structures was not possible This may explain the resulting septic arthritis of the knee which was due to a breakdown of the articular cartilage and drainage of the pus into the knee joint The clinical signs were those of an acute arthritis of the knee, although the X ray remained negative for 3 weeks

In all three cases an accurate diagnosis and suitable treatment were delayed because the condition is rare and it presented in an atypical manner According to the literature the usual organism found is *staphylococcus aureus* although occasionally *streptococcus* is cultured Reports have been published of tuberculosis, syphilis and mycosis of the patella In our three cases no organisms were cultured from the aspiration fluid sequestrum or the synovial tissue but treatment with antibiotics had been initiated at this stage

The treatment program of the cases reported in the literature is not uniform, in a few cases the condition was cured with rest and antibiotics In other cases a sequestrum was removed Our trial with initial conservative treatment, consisting of antibiotics and rest was unsuccessful in all three cases so that operative treatment was performed with removal of the sequestrum In case 1 a large sequestrum was removed, representing the whole bony nucleus of the patella Further ossification seems to develop normally but the patella is larger than the contralateral one The postoperative course was uneventful and full recovery of knee function was achieved in all cases

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Acta orthop scand 47 570 574 1976

INTRAOSSEOUS LIPOMA OF THE CALCANEUS

Report of a Case and a Short Review of the Literature

MIKKO POUSSA[1] & TEDDY HOLMSTROM[2]

[1] Department of Orthopedics and Traumatology, University Central Hospital, Helsinki and [2] Third Department of Pathology, University of Helsinki Helsinki Finland

One case of an intraosseous lipoma of the calcaneus bone is presented together with a short review of the literature Only 20 cases of tumor in the extremities have so far been published The typical X ray picture shows a cystic, sharply demarcated cavity which macroscopically at operation is filled with yellowish adipose tissue In the present case and one previously published a central sclerotic mass was observed The histological picture is typical with mature adipose tissue mixed with a few degenerated bone trabeculae

Key words intraosseous lipoma, calcaneus

Accepted 20 v 76

Despite the large amount of adipose tissue in bone marrow, intraosseous lipomas are very rare tumors Since the first report by Wehrsig in 1910 of a lipoma in the proximal part of the fibula, 20 cases of intraosseous lipomas of the limbs have been reported For intraosseous lipoma, Dahlin (1967) has reported an overall incidence of one per 1,000 bone tumors Periosteal lipomas are much more common, and if the tumor corrodes the underlying bone, the true point of origin of the lipoma is difficult to ascertain (Caruolo & Dahlin 1953)

Child reported the first case of intraosseous lipoma in the calcaneus bone in 1955 and Appenzeller & Weitzner reported an additional case in 1974

We report one further case with emphasis on the typical X ray and histological picture

CASE REPORT

The patient, a 41 year-old female dentist was admitted to hospital in 1973 when an X ray taken because of painful ankles revealed a cyst in the left heel bone She recalled a weak contusion trauma to both feet 20 years earlier She had suffered from pain in the joints of her hands and feet for 10 years but nothing specific was revealed in the examinations In 1965 an arthrotomy was performed on her left knee joint, both menisci were ruptured and removed

The physical examination for the present disease showed nothing abnormal and the laboratory analyses were all normal

The X ray showed a 2 × 2 5 cm sharply demarcated cyst with a 5 × 10 mm large sclerotic nidus in the center in the collum of the calcaneus (Figure 1) The radiologic diagnosis was benign bone cyst

Curettage of the lesion was performed on May 29 1973 under general anesthesia The specimen consisted of yellowish adipose tissue with two harder fragments in the middle The cyst was filled with spongy bone

Histological examination revealed mature adipose tissue in which a small amount of thin often degenerated bone trabeculae could be found (Figure 2) In the middle of the tumor



Figure 1 Lateral radiograph of left calcaneus Note the sclerotic nidus in the center of the well circumscribed cyst

irregular areas of cell free amorphous calcified tissue were seen (Figure 3) Adjacent to these areas the tumor was rich in thin collagen fibers The number of blood vessels was not prominent *Hemosiderin was not present* No cellular atypia or other signs of malignancy could be detected *Both radiographic and histological* findings were typical for intraosseous lipoma

DISCUSSION

The most common location for intraosseous lipomas of the extremities is the metaphysis of the long bones Table 1 summarizes the cases published so far No predilection for age or sex is observed The symptoms if present, are nonspecific Pain and swelling or both especially after exercise are the most common symptoms and have often been present for many years In the case reported here the patient was asymptomatic

The radiographic picture of intraosseous *lipoma is not specific* In fact almost all cases had been diagnosed as *other benign cystic lesions of bone and* even incorrect malignant diagnoses had

Figure 3 Photomicrograph showing mature adipose tissue and a thin partly atrophic bone trabecula (H & E × 100)

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been suggested (Caruolo & Dahlin 1953) The usual appearance is a radiolucent, well circumscribed cystic lesion within the marrow cavity and expansion and subperiosteal bone formation are sometimes seen Trabeculae producing a loculated appearance are seen in many of the lesions In one previous case (Appenzeller & Weitzner 1974) a central, sclerotic nidus was demonstrated, and in the present case the X ray picture is analogous

In all cases reported, the histological picture is typical for lipoma Mostly thin atrophied bone trabeculae are seen in the mature adipose tissue In only two cases were the trabeculae missing (Caruolo & Dahlin 1953 Thevenot et al 1965) and in the present as well as one previous case (Appenzeller & Weitzner 1974) a central area of calcified material is seen Cellular atypism cellularity or some other evidence of confusion with liposarcoma have not been reported and the differential diagnosis between lipoma and liposarcoma should not be difficult

The exact nature of intraosseous lipoma has been widely debated in the literature and the pathogenesis has been extensively discussed by Hart (1973) Most authors however agree upon a true benign neoplasm arising in the adipose tissue of bone medulla Central calcification is most probably caused by hemorrhage that may have been traumatically induced in a pre existing lipoma In the present case as well as in many previous cases (Mueller & Robbins 1960 Smith & Fienberg 1957 Bagnoud et al 1967) the history of trauma is positive Appenzeller & Weitzner (1974) also strongly support trauma as an etiological factor although their own case is negative in that respect

The therapy should be curettage and filling of the cavity with cancellous bone More radical surgery is not needed and no recurrences have been reported to our knowledge

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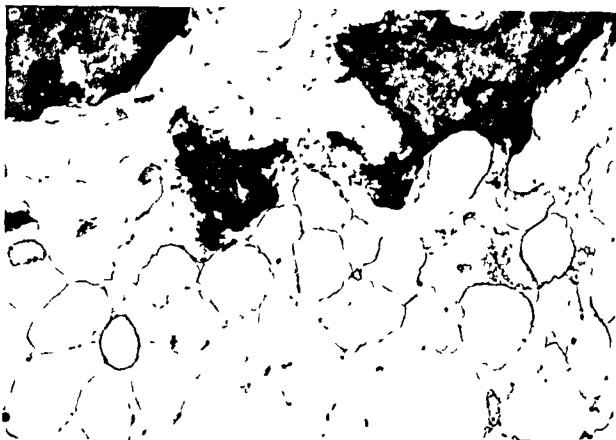


Figure 3. Photomicrograph from the central part of the tumor showing irregular calcified cell-free masses in mature adipose tissue. Note thin collagen fibers adjacent to the calcifications (H & E × 180).

Table 1. Locations of the intraosseous lipomas of the limbs reported in the literature

Location	Number	Sex	Age (years)	Author and year
Proximal femur	1	Male	62	Dahlin 1967
Distal femur	2	?	?	Brault 1901
		Female	58	Gennari & Bozzetti 1965
Proximal tibia	4	Female	32	Mastromarino & Assennato 1957
		Male	21	Salzer & Salzer-Kuntschik 1965
		Male	30	Bagnoud et al. 1967
		Female	33	Hart 1973
Distal tibia	2	Male	30	Dickson et al. 1951
		Male	14	Mueller & Robbins 1960
Proximal fibula	2	Female	5½	Wehrsig 1910
		Female	57	Smith & Ilenberg 1957
Distal fibula	3	Male	15	Peloux et al. 1965
		Female	20	Thevenet et al. 1965
		Male	14	Azizi 1968
Calcaneus	3	Male	22	Child 1955
		Male	59	Appenzeller & Weitzner 1974
		Female	41	Poussa & Holmström 1976
Proximal humerus	2	Male	56	Skinner & Fraser 1957
		Male	41	Kaganskii 1963
Proximal ulna	1	Male	44	Caruolo & Dahlin 1953
Distal phalanx thumb	1	Female	70	Ackerman & Spjut 1962

Acta orthop scand 47 57‑–577 1976

PROCEEDINGS OF THE SWEDISH ORTHOPAEDIC ASSOCIATION

Skövde, May 23 24, 1975

EDITOR BO E NILSSON

TARSAL TUNNEL SYNDROME

S A Ahlgren & A Rydholm
Skövde

Nerve entrapment in the tarsal tunnel was diagnosed in 16 cases Five were post traumatic and the remainder of unknown origin The ages of the patients ranged from 12–73 years Only one third of the cases were men In addition to the usual signs some of the patients habitually walked on the lateral edge of the foot in order to relieve the pain All patients were operated on resulting in complete relief in 12 cases and improvement in three

SURGICAL TREATMENT OF THE ULNAR NERVE SYNDROME

H Lugnegård G Walheim & A Wennberg
Stockholm

Twenty five patients were re investigated after operative treatment of ulnar nerve syndrome with transposition of the ulnar nerve About one third were post traumatic and one third alcoholics Out of the 25 patients 21 were improved in one way or another In most cases some objective sign of improvement could be noticed such as improved sensibility recovery from paresis or improved nerve impulse velocity Alcoholics or patients who were over 50 years of age appeared to have a less favourable post operative course

KNEE PAIN IN ELDERLY PATIENTS

C Bauer
Lund

The development of diagnostic procedures and the recent additions to our knowledge of knee disease makes [illegible] a particularly interesting branch of orthopedic surgery Methods such as weight bearing radiography radioisotope scintimetry crystal analysis and arthroscopy have proved to be useful procedures in the early diagnosis of knee disease The concepts of focal arthrosis in the knee joint of osteonecrosis and of crystal synovitis have clarified the confused diagnostic pattern In knee disease, abnormal function usually becomes evident at an early stage In the elderly, early symptoms generally lead to a rational diagnosis for which effective treatment is usually available

A SOLUTION OF THE HAND PROSTHESIS PROBLEM

F Moberg
Göteborg

(*Film presentation*)

The Krukenberg operation of forearm amputees should be combined with a hand prosthesis This solution offers the patient two possibilities depending on the *circumstances* The prosthesis should be so constructed that opening of the Krukenberg grip closes the *hand grip and vice versa* With this technique *afferent impulses* are obtained for direction position and pressure The key grip should be *preferred* to the three pulp pinch

OSTEOCHONDRITIS DISSECANS AND CHONDROCALCINOSIS

R Lindén
Malmo

Radiographical signs of chondrocalcinosis were found in about 50 per cent of all patients who had *previously* been diagnosed as having osteochondritis [illegible] oste[illegible] in [illegible] lines, chondrocalcinosis was rare Clinical findings and symptoms did not differ between patients with and without the chondrocalcinosis sign Among the osteochondritis cases chondro-

Thevenot, P, Peloux Y & Michelin C (1965) Le lipome intramédullaire osseux A propos d un deuxième cas observé au Dahomey *Med trop* 25 745–748

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THE RELIABILITY OF RADIOGRAPHIC MEASUREMENTS OF THE NORMAL DISTAL RADIAL JOINT

S Friberg & B Lundstrom
Lund

The inclination of the distal radial joint in relation to the long axis of the radius was analysed in radiographs of 60 normal wrists in 50 adults The wrists were examined with the central ray angled 10° proximally in the postero anterior projection and 15° proximally in the lateral projection The results from the angled projections were compared with those obtained from perpendicular projections In the postero anterior projection no differences in results were found between the two projections used (mean value 25°) In the lateral projection the exactness of the measurements was significantly increased when the central ray was angulated 15° proximally (mean value perp 14 5° angul 9 3°) Only minor differences (mean 1°) were f und between the two wrists of the same individual

HOW TO IMPROVE SCOLIOSIS TREATMENT IN SWEDEN

A Nachemson
Goteborg

Today treatment of scoliosis is justified beyond any doubt In addition methods and results are well established The problem in Sweden at the present time is to find the means f distributing modern scoliosis therapy to those wh need it It can be calculated that in Sweden with a population f 8 million 300 new cases will be diagnosed annually all of which are severe enough to need treatment and one third f which need surgery To deal with these patients 25 hospital beds will be constantly required Also there is a backlog of about 500 cases already skeletally *mature* who would benefit from immediate treatment These patients require another eight hospital beds for the next 5 years In addition about six beds will be needed f r special cases e g for the treatment f c ngenital cases and meningomyel cele with hal pelvic traction and the Dwyer procedure Annual availability included the health authorities in Sweden will have to provide altogether 40 h pital beds with the relevant resources th s must be d ne without delay

AN ANALYSIS OF NATIONAL EXAMINATIONS IN ORTHOPEDIC SURGERY 1971 1974

F Spangfort
Huddinge

Alt gether 1200 multiple-choice questions used in the national examinati n in surgery for interns and medical students were surveyed Twenty seven per cent of the questions dealt with orthopedic surgery The frequency of questions on various items was fairly proportional to the attention paid to the same items in the teaching However three subjects were poorly represented Social orthopedics including technical aids and disability evaluation surgery in rheumatoid arthritis and congenital malformations, particularly in questions for interns

NOMOGRAPHIC RECORDING OF HIP MOBILITY

F Spangfort
Huddinge

A nomogram was constructed for the recording of the range of motion of the *hip joint* It provides a simple means of registering all qualities of motion in the joint and can be applied to most cases Reading and recording errors are less common with this method of recording

HIP ARTHROPLASTY

T Christiansen (Guest lecturer)
Kongsberg Norway

The development the hypothesis and the results of the Christiansen hip prosthesis were presented by the inventor

DISLOCATION OF THE CHARNLEY HIP PROSTHESIS

C H Hybinette & L Lindberg
Lund

Out of a total of 510 operated hips 38 (8 per cent) had dislocated at one time or another Dislocation within the first week after surgery even if the dislocation recurred during the hospitalization *period did not lead to* recurrent dislocation later on thus providing no problem Between 1 and 6 weeks a few cases dislocated one of which became a problem later on Only cases in which the first dislocation was recorded later than after 6 weeks tended to recur time after time and to cause discomfort to the patient Twelve of the cases of dislocation had been operated on previously The surgeon s experience and skill could not be shown *to influence* the tendency of dislocation but with a posterior approach dislocation was twice as common as with the standard lateral appr ach

calcinosis was found almost exclusively in individuals who had been operated on. In these individuals chondrocalcinosis was significantly more common than in a sample of patients operated on for a torn semilunar cartilage. The changes were identified as pyrophosphate and, in one case, as hydroxyapatite deposits in the cartilage.

KNEE ARTHROPLASTY WITH A ST GEORGE CONDYLAR PROSTHESIS (SCHLITTENPROTHESE)

U. James
Uddevalla

Thirty six joints in 34 patients, 27 with gonarthrosis and 7 with rheumatoid arthritis, were operated on and fitted with a St George condylar prosthesis. In all but four cases only one part of the femoro tibial articulation was operated on, usually the medial. At the time of follow up, on average after 18 months, the range of motion was unchanged (5–110°) in patients who had been operated on with one prosthetic replacement. Although half of the patients suffered rest pain at the time of operation, there was none with rest pain after surgery. Only two patients complained of symptoms which could be referred to the femoro patellar joint.

For the cases fitted with a double prosthetic replacement, the range of motion was 15–90°. Postoperatively their progress was somewhat slower. In two cases with a medial replacement there was loosening of the prosthesis, which was successfully replaced. Otherwise there were no serious complications. Only joints with correctable angular deformity but which are otherwise stable should be treated by this method. In more severely damaged joints, a hinge prosthesis should be used.

INTERMITTENT RADICULAR CLAUDICATION

Y. Surin
Borås

Eight patients with unilateral intermittent radicular claudication were described. Their walking distance until disabled by pain ranged from 50–200 metres. There were no signs of impaired arterial flow. In four cases the straight leg raising sign was positive; four patients had mixed and disseminated neurological symptoms. In all eight patients there was evidence of a narrowing of the spinal canal based on a positive contrast myelogram. A discrepancy existed between the severe symptoms and the meagre clinical findings. Six patients were operated on with decompressive laminectomy. Three were completely relieved of symptoms and the remainder were improved.

SUPRACONDYLAR FRACTURE OF THE HUMERUS IN CHILDREN

B. Frisl, U. James & K. Undeland
Uddevalla

Forty children with supracondylar fracture of the humerus were followed up for 8 months–5½ years. Thirteen patients had been treated with plaster fixation and 29 by traction. The cases with the most severe dislocations were selected for treatment with traction. Of the 13 cases in plaster fixation, three were later on treated in traction owing to complications. In six cases neurovascular disturbances were noted during the course of the treatment, but all six made a complete recovery. Comparison of the final results of the two groups, plaster fixation and traction, showed no differences although patients treated in traction had originally suffered the more severe dislocation.

INJURIES CAUSED BY LAWN MOWERS

R. Kalén
Danderyd

Fifteen injuries caused by motor lawn mowers were surveyed. Only two were caused by cylinder mowers, whereas the remainder were caused by rotating blade mowers. One pattern was repeated in seven cases. A rotating blade mower is being pushed downhill on slippery ground. The patient loses his balance, pulling the mower backward over his foot and amputating 1–4 toes.

PEDICLE BONE GRAFTS IN PRIMARY SURGERY OF CERVICAL FRACTURE OF THE FEMUR

G. Hallin
Falun

Six months experience of pedicle grafts in combination with pinning or screwing of femoral neck fractures was presented. The method incurred increased effort and time. Long term results were not available.

SUCTION DISSECTOR IN DISC SURGERY

R. Axelsson & S. Smeds
Mölndal

A combination of suction handle and dissector was constructed; it is particularly suitable for surgery of herniated discs. Experience with the instrument has been favourable in that it has allowed for smooth and less traumatic surgery and has saved time.

onarthritis. Following persistent pain localized to a limited area of the nail fold without objective signs, an explorative incision revealed a typical bluish glomus tumour.

A 45 year old woman had a negative explorative incision because of suspected Morton's metatarsalgia. One year later the patient discovered a small bluish swelling on the distal phalangeal joint of the third toe. Histology of the excised swelling confirmed the glomus tumour diagnosis. Both patients are relieved of their pain.

The diagnosis of glomus tumour is often difficult because it is rare and most frequently mon symptomatic.

TOTAL PROSTHESIS OF THE KNEE

Cato Hellum
Kronprinsesse Marthas Institutt, Oslo

During the last 5 years the Guepar prosthesis has been inserted into 31 knees. Thirty had rheumatoid arthritis, five knees had been operated on previously, and five had ankylosis of the contralateral knee.

The operation was carried out via a medial parapatellar incision. During the first week the patient is in a plaster cast in bed. Knee exercises in bed are begun in the second week. Weight bearing begins after 2 weeks. If flexion is less than 50° (12 knees) then mobilization under anaesthesia is carried out after 3 weeks.

The results were good in 21 cases. There was occasional pain or swelling in four cases and six were noted as poor. Of the six poor results in one the stem perforated the femur and there was very limited mobility, one had infection and an almost complete ankylosis, and one had an infection and prosthesis removal. Three patients with infection were able to walk around during antibiotic treatment with only slight symptoms but a flare up occurred if medication was stopped.

Eight knees were under steroid medication. This does not seem to influence the results or the occurrence of complications. The most important factor is to obtain a good primary wound healing.

OSTEOID OSTEOMA

Harald Russwurm & Lasse Kvarnes
Kronprinsesse Marthas Institutt, Oslo

Osteoid osteoma has been reported in almost every bone of the skeleton. The age group of predilection is 10 to 26 years. The most important clinical characteristic is pain. Diagnosis depends upon radiological evidence. Excision of the lesion leads to relief of pain.

Four patients with osteoid osteoma seen in the last two years are reported. There were two lesions in the lumbar spine, one in the humerus and one in the fibulae. The age range was 11–18 years. The symptoms were pain and scoliosis when located in the spine. The radiological findings were typical. All patients were operated on and obtained complete relief of pain.

PIGMENTED VILLONODULAR SYNOVITIS

Giste Uppheim
Kronprinsesse Marthas Institutt, Oslo

A case of pigmented villonodular synovitis starting as a localized tumour in a knee joint and later developing into a diffuse synovitis was presented.

The various aetiologies postulated for the disease were discussed. The most important differential diagnosis is a synovial sarcoma. The treatment of choice seems to be excision of the tumour in the nodular form and radical synovectomy in the diffuse form. There is however a disappointingly high recurrence rate. Most authors reserve radiotherapy for cases in which other treatment has been unsuccessful.

Oslo, March 20th, 1976

EXTERNAL FIXATION AD MODUM ADREY VIDAL

Arne Haukela
Ullevål Hospital, Oslo

In 1971 Adrey from Vidal's Clinic in Montpellier presented his biomechanical study in which he used various modifications for the mounting of Hoffmann's "fixateur externe" (f.e.). He showed that mounting in a "double coupled frame" allowed not only the most rigid immobilisation but also could give a very good compression of the fracture. In addition it was possible to do bone grafting and soft tissue operations with the f.e. in place.

Four cases, one compound fracture of the leg and three infected non-unions of the leg treated with the Adrey-Vidal modification of Hoffmann's f.e. were presented. The results of the treatment were most satisfactory.

Acta orthop scand 47 578 581 197(

PROCEEDINGS OF THE NORWEGIAN ORTHOPAEDIC ASSOCIATION

Oslo, January 24th, 1976

SOME RLFLECTIONS ON MENISCECTOMY

Leif Oystein Heen
Aker Hospital Oslo

Fifty two meniscectomies 44 medial and 8 lateral were reviewed In 20 cases operated on because of clinical indications all had meniscal lesions In 32 cases where the diagnosis was supported by a positive arthrography 5 had a normal meniscus

Forty two patients were interviewed 3–24 months postoperatively Eighteen patients still had knee problems Considering these figures the author recommends an expectant attitude to minor knee complaints even if lesion of the meniscus is suspected

RADIAL NERVE PALSY IN HUMERAL FRACTURES

Ulf Slungaard
Aker Hospital Oslo

Four instances of closed humeral fracture with complicated radial nerve palsy are reported Complete nerve recovery in 2 5 months occurred in all cases

Complete nerve recovery can be expected in more than half of these cases and a conservative attitude seems to be wise An EMG registration 3 4 weeks after injury will probably g e information as to whether or not spontaneous recovery can be expected

BONE INVADING SQUAMOUS CELL CARCINOMA FROM THE MARGIN OF A CHRONIC ULCER

Adolf Mollerud
Aker Hospital Oslo

Squamous cell carcinoma originating in a chronic ulcer and invading underlying bone i usually accompanied by severe pain Two cases of this type in male patients are reported Both showed infiltration of the tibia and the characteristic pain The squamous cell carcinoma originated in a chronic varicose leg ul er in one and in a sinus from chronic osteomyelitis in the other Amputation was necessary in both cases

Oslo, February 14th, 1976

ALKAPTONURIA OCHRONOTIC ARTHROPATHY

Olav Reikeras
Kronprinsesse Marthas Institutt Oslo

Alkaptonuria is an inherited disorder of the tyrosine catabolism Lack of homogentisic acid oxidase leads to accumulation of homogentisic acid and its oxidation polymer a melanin looking pigment with affinity for mesenchymal tissue which is discoloured blacl —ochronosis

Homogentisic acid causes a dark colouration of urine on standing This is accelerated by all ali

Clinically the condition appears by mid adult life with black discolouration of sclerae and ears and often with degenerative arthropathy involving the spine knees hips and shoulders The roentgenogram of the spinal column is characteristic with laminated calcifications of the intervertebral discs

Two patients with ochronotic arthropathy are reported both manifesting all the typical signs and symptoms of all aptonuria

GLOMUS TUMOUR

Arne Rugtveit
Kronprinsesse Marthas Institutt Oslo

Two instances of glomus tumour in patients who previously underwent surgery on the grounds of an incorrect diagnosis are presented.

In a 60 year old woman an arthrodesis of a distal interphalangeal finger joint was performed because of suspected unspecific painful

monarthritis Following persistent pain localized to a limited area of the nail fold without objective signs an explorative incision revealed a typical bluish glomus tumour

A 46-year old woman had a negative explorative incision because of suspected Morton's metatarsalgia One year later the patient discovered a small bluish swelling on the distal phalangeal joint of the third toe Histology of the excised swelling confirmed the glomus tumour diagnosis Both patients are relieved of their pain

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Four cases one compound fracture of the leg and three infected non unions of the leg treated with the Adrey Vidal modification of Hoffmann's f.e. were presented The results of the treatment were most satisfactory

THE USE OF BONE CEMENT AS AN ADJUNCT IN THE INTERNAL FIXATION OF SUPRACONDYLAR FRACTURES OF THE OSTEOPOROTIC FEMUR

Pål Benum
Ullevål Hospital, Oslo

Bone cement was used as an adjunct in the internal fixation of 14 supracondylar femoral fractures. The fractures were stabilized with ASIF plates. In all these fractures the severe osteoporosis found during operation made a stable internal fixation without use of bone cement impossible. The average age of the patients was 75 years. Eight of the patients had previously been operated because of fractures of the same extremity and three suffered from disabling diseases.

Twelve fractures healed without complications despite early mobilization. One fracture needed additional external fixation before it healed and one led to non union. No infections were seen.

It is concluded that use of bone cement as an adjunct in the internal fixation of supracondylar fractures enables a stable fixation even in the most severe osteoporotic femur and leads to healing in most cases of such fractures.

Oslo, April 24th, 1976

PSEUDARTHROSIS TIBIAE CONG.

O. H. Brinchmann Hansen
Hagevik Orthopaedic Hospital
Hagevik

Five cases of crus curvatum cong. were demonstrated. Three of the cases displaying antecurvation and varus deformity of the leg developed pseudarthrosis of the tibia. Two went to amputation following several unsuccessful operative procedures. After several attempts with plating and homologous bone transplantation the third healed after delayed autogenous bone grafting. All these three patients had signs of neurofibromatosis. In two cases the tibia did not fracture. One of those had a recurvated and valgus deformed leg, the other patient's leg was antecurvated and varus derformed. These two patients had no signs of neurofibromatosis. The good result obtained by delayed autogenous grafting where all other operative procedures failed was emphasized.

OSTEOCHONDRITIS DISSECANS OF THE KNEE JOINT
Treatment with tibial autografts

Ole Dankert Lunde
Hagevik Orthopaedic Hospital
Hagevik

The problems in separating anomalies of ossification from osteochondritis dissecans were discussed.

In 23 patients with osteochondritis dissecans 20 were treated using tibial autografts for fixation and two had separated fragments. A detailed description of the operative technique was given. In all patients revascularisation appeared and normalisation of the pathological lesion. The structure of the bone was normal and the autografts were completely incorporated.

The clinical results were reported.

Oslo, May 22nd, 1976

OSTEOARTHRITIS OF THE KNEE JOINT TREATED WITH REMOVAL OF THE OSTEOPHYTES

Jette Johansen
Østfold County Hospital
Fredrikstad

Fifty seven random patients with osteoarthritis of the knee were operated on after conservative treatment was unsuccessful. This involved an arthrotomy and removal of the osteophytes. Due to short parapatellar incisions the postoperative training caused no problem. Half of the patients returned to their former occupation. Follow up period 3 months to 10 years. Two patients treated with the same technique 20 years ago are still doing well.

FURTHER EXPERIENCE WITH PES ANSERINUS TRANSPLANTATION

Erik Lie
Østfold County Hospital
Fredrikstad

Fourteen patients all presenting a rotatory instability of the knee joint had a pes anserinus transplantation six months to six years after the original trauma. In 10 patients with a follow up period of 3 to 7 years the functional

improvement of stability has justified this procedure as routine for rotatory instability

RHEUMATOID SURGERY IN A COUNTY HOSPITAL

Lr f Fg l Nygaard
Østfold County Hospital
Fredrikstad

In the county of Østfold an increasing number of patients have had operations for rheumatoid arthritis in the orthopaedic department. Because of lack of beds at present less than 10 per cent of the assumed patients who need surgery receive it.

The importance of early synovectomies is stressed before gross destruction of joints and tendons has occurred.

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If the lidocain injection eliminates the sciatica the surgeon can feel confident of the existence of true nerve root compression in deciding on an exploration. In a series of 19 patients the correlation between the localization of the compression and the level indicated by the test was confirmed during surgery.

VASCULAR LESIONS IN RECONSTRUCTIVE HAND SURGERY MATERIAL

K. S. Ionen, M. Vastamaki & S. Vilkki
Section of Hand Surgery, Orthopaedic Hospital of the Invalid Foundation, Helsinki

Reference is made to 48 patients with arterial injuries in the upper extremities and to 19 patients with various arterial, venous and arteriovenous diseases. In the former group 53 arterial reconstructions with vein grafts were performed. At the follow up ½–4 years later the brachial artery was open in 6/7, the radial artery in 9/14 and the ulnar artery in only 5/32 cases. The patients in the series of vascular diseases were given various types of surgical treatment. The results were satisfactory in all cases. In spite of the not very satisfactory results in the former group it was concluded that in selected patients and with increasing skill and experience even distal arterial lesions could be considered for reconstruction.

ULTRASONIC DOPPLER FLOWMETER IN THE DIAGNOSIS OF VASCULAR LESIONS OF THE UPPER EXTREMITY

Simo K. Vilkki
Section of Hand Surgery, Orthopaedic Hospital of the Invalid Foundation, Helsinki

The Doppler ultrasonic flowmeter represents a practical, relatively inexpensive, noninvasive method for the transcutaneous evaluation of peripheral arterial or venous flow pre-, intra- and post-operatively in hand surgery patients.

It is stressed that a particularly good knowledge of the vascular anatomy and haemodynamics of the hand is necessary for reliable interpretation of the Doppler sounds.

It appears that the use of the ultrasonic flow meter diminishes the need for angiography.

MODIFICATION OF KRUKENBERG'S KINEPLASTIC OPERATION

V. Ritsila & R. Kivilaakso
Orthopaedic Hospital of the Invalid Foundation, Helsinki

Little attention has been paid lately to the kineplastic operation of amputation stumps. Krukenberg's procedure, the forcipisation of forearm amputation stumps introduced in 1917, has nevertheless survived. The authors have modified the operation. The skin of the forearm is split with a L-shaped incision. All muscles are preserved. The interdigital commissure is covered with two triangular flaps. The remaining skin defect is left on the dorsum of the radial branch and covered with a free split skin graft. The skin graft is not used to cover the contact surface. In the Orthopaedic Hospital of the Invalid Foundation in Helsinki nine forearms of seven patients were operated on with this method during the period 1969–1973.

Jyväskylä, Finland, 14 May 1976

AO OSTEOSYNTHESIS IN THE TREATMENT OF FRACTURES OF THE FEMORAL NECK

P. Lähde & A. Santén
Orthopaedic Department,
Central Hospital of Central Finland,
Jyväskylä

In Finland the incidence of fracture of the femoral neck is 40 cases per 100 000 a year. This injury accounts for one fourth of all fractures treated operatively.

In the Central Hospital of Central Finland osteosynthesis has been performed using the AO technique. Thompson's endoprosthesis has been used with some patients over 70 years old with subcapital fractures. Immediate weight bearing has been permitted as the postoperative treatment. A follow up examination has been performed after 1, 3 and 6 months.

In 1972–74 190 patients were treated. AO osteosynthesis was applied to 151 patients and Thompson's endoprosthesis to 39 patients. The average age was 71 and the average length of treatment in hospital was 23 days. There were 71 fractures of the femoral neck and 80 trochanteric fractures. The mortality among the 151 patients after 2 weeks was 3.3 per cent, after one month 6.6 per cent and after 6 months 15.9 per cent. We consider the low mortality to be due to immediate postoperative weight bearing and to the careful pre and postoperative treatment. 100 patients, i.e. 78.7 per cent, attended the follow up examinations. Six months after the opera

Acta orthop scand 47, 582 584, 1976

PROCEEDINGS OF THE FINNISH ORTHOPAEDIC ASSOCIATION

Helsinki, Finland, 13 March 1976

PITFALLS IN ENDOPROSTHETIC SURGERY

Kauko Vainio
Heinola

Orthopaedic surgeons have been interested in replacing joints since 1890 when three tuberculous knee joints were replaced using a hinge prosthesis made of ivory All failed because of rejection In the 1920s metallurgists succeeded in producing several durable alloys It was believed that the problem was solved However, loosening of the prosthesis due to infection (in spite of strict asepsis) or metal sensitivity has occurred much too often Toxic metal ions spread into the circulation from the prosthesis Their toxicity has been demonstrated by macrophage cultures, pure titanium seems to be the least toxic Ceramic prostheses made of the purest aluminium oxide are non toxic but unfortunately are brittle It is now generally agreed that a metal to plastic system releases less metal particles than a metal to metal system Hinge joints are often biomechanically unsatisfactory and should be used only as a last resort In the hand metal hinge prostheses fail because of stiffening Also the St George type of prosthesis has a tendency to stiffen after a couple of years Our experiences of the Calnan Nicolle prosthesis are disappointing with many fractures or perforations of the cortex Hagert has demonstrated breakage dislocation and cortical perforation of the silicone prostheses

RESULTS OF REVISION OPERATIONS FOLLOWING LOOSENED AND INFECTED TOTAL HIP PROSTHESES

T Visuri & I F Laurent
Orthopaedic Hospital of the Invalid Foundation
Helsinki

Forty two revisions were carried out reapplication was performed in 34 cases and a removal of the prosthesis in 8 cases Reapplication is indicated in patients with loosening due to trauma and *in cases* with malpositioning of parts of the prosthesis There were poor results after reapplication of infected and/or dislocated hips Palacos with gentamycin was not used in this series

SPONDYLITIS IN CHILDREN

S Ryöppy J Jaäskeläinen & I Louhimo
Children's Hospital
Helsinki University Central Hospital

Twenty two patients treated for spondylitis during the period 1961–1975 were divided into three groups tuberculosis – 3 cases patients treated with antituberculous drugs without verified tuberculosis – 8 cases and nonspecific spondylitis – 11 cases The analysis was focused on the last mentioned group

The clinical picture in nonspecific spondylitis was clear, and a suspicion of an intervertebral disc space process was often confirmed before the occurrence of any radiological changes which appeared about 4 6 weeks after the onset of symptoms

An operative biopsy was performed in 8 cases and showed a subacute inflammation The bacterial culture was positive in one case (*staph aureus*) All patients were treated with *bed rest* and antibiotics for 6–27 weeks (average 1[illegible] weeks) All patients were clinically normal at the follow up (average 14 months) *Radiologically* only one was normal but no interbody fusion was observed

The last case of tuberculous *spondylitis* in this series was in 1965 No spinal affections have been observed in sporadic Calmette (BCG) tuberculosis Since 1968 routine *exploration* has eliminated the need for antituberculous treatment and has shown that the process is a disc space inflammation of in most cases unknown etiology with a tendency to rapid healing and a good prognosis

SPINAL NERVE BLOCK A DIAGNOSTIC TEST IN SCIATICA

P Jussila & F W[illegible]lppula
Department of Orthopaedics and Traumatology
Helsinki University Central Hospital

The cause of sciatica can be investigated by blocking the spinal nerves of the lumbosacral plexus at their intervertebral foramina Selective identification of these nerves is accomplished by the injection of 1 ml of 1 per cent lidocain (Xylocain®) and the use of an image intensifier

Acta orthop scand 47, 585-587, 1976

NUCLEIC ACIDS IN HUMAN NORMAL AND OSTEOARTHRITIC ARTICULAR CARTILAGE

HANS TELHAG

Department of Orthopaedic Surgery, Malmo General Hospital, University of Lund, Malmo, Sweden

During operations on joints of patients with osteoarthritis, specimens of severely degenerated cartilage of the femoral head were removed and cartilage from knee joints taken at meniscectomy was used as control material DNA and RNA concentrations were reduced in advanced osteoarthritis, while the synthesis of DNA and RNA was increased in relation to the number of cells in the tissue The result showed that in advanced osteoarthritis the remaining chondrocytes are metabolically very active

Key words nucleic acids, articular cartilage, human osteoarthritis, chondrocytes

Accepted 31 viii 76

Joint cartilage is a unique tissue whose structural biochemical and metabolic characteristics were unknown until a few decades ago During the last three decades the biochemistry and metabolism in normal and in osteoarthritic cartilage have received wide attention

It has been shown that experimental degenerative cartilaginous changes in rabbit cartilage are not accompanied by any change in DNA and RNA concentrations (Telhag & Gudmundson 1972) The concentration of DNA in man has also been shown to be the same in normal and in osteoarthritic cartilage (Mankin & Lippiello 1970, Mankin et al 1971) A search through the literature failed to reveal any determinations of the RNA concentration in normal and in osteoarthritic cartilage in man The purpose of the present investigations was to elucidate the synthesis and concentration of nucleic acids in normal and osteoarthritic cartilage in man

MATERIAL AND METHODS

Articular cartilage was obtained during operations on human joints Specimens were taken from the femoral head in 29 patients, aged 65 ± 8 (range 46 79), with osteoarthritic degeneration of the hip The specimens were taken from macroscopically thin, fibrillated and partly eroded cartilage with grade 3 and 4 degeneration of the femoral head (Collins 1949). Control biopsy specimens were taken from a non-weight bearing area of the medial femoral condyle during operations because of injuries to the meniscus in 17 knees from patients, aged 36 ± 10 (range 21-46), without osteoarthritis The car-

[illegible] or operation The samples were divided

Financial support was obtained from Riksf r bundet mot Rheumatism Ulla och Gustaf af Ugglas fond and Alfred Osterlunds Stiftelse

tion the nailing results were poor in 16 per cent

PUTTI PLATT OPERATION IN THE TREATMENT OF RECURRENT ANTERIOR DISLOCATION OF THE GLENOHUMERAL JOINT

Pentti Rokkanen & Tapio Tervo
Orthopaedic Department
Central Hospital of Central Finland
Jyväskylä

The Putti Platt operation has not been widely used in the Scandinavian countries (Stolt Nielsen and T Johnson *T Norske Laegeforen* 1974 94 1383)

Since 1972 we have used only the Putti Platt operation (Osmond Clarke I *Bone Jt Surg* 1948 30 B 19) for recurrent dislocations of the glenohumeral joint This report is a preliminary analysis of the first 30 patients who were followed for one year after their operations The series comprised 20 men and 10 women with an average age at the time of the operation of 33 years (range 18 to 60) The interval between the operation and return to work was 53 days on average Postoperative immobilization was effected by a Velpeau bandage for three weeks Outward rotation was allowed six weeks after the operation

The patients subjective views regarding the *final results as indicated at the follow up* examination were good in 17 cases (objectively in 20) fair in 12 cases (objectively in 9) and poor in one case (objectively in 1) The patient in question had recurrent subluxations after the operation

ACROMIOCLAVICULAR DISLOCATION

Veikko Avikainen
Central Hospital of Central Finland
Jyväskylä

The large number of methods for handling the total dislocation of the acromioclavicular joint (gr III) shows how unsatisfactory results can be In the Central Hospital of Central Finland we have used an AO cortical screw from the acromion to the clavicula for stabilisation Coracoclavicular and acromioclavicular ligaments are sutured The screw is removed 4-6 weeks after the operation and the mobilisation is started

Between 1972 and 1975 19 patients were operated on and followed for at least 6 months Special attention was paid to pain reduced strength and limitation of mobility The results were excellent or good in 74 per cent satisfactory in 11 per cent and poor in 15 per cent of the cases Redislocation occurred twice Redislocation and the appearance of ligament calcification in x ray had no influence on the result On the other hand the increased age of the patients and the delayed removal of the screw impaired the results The results are comparable to other results published The merits of screw fixation are technical facility and good stability The results from an early operation were better than those of the six lateral resections of the clavicula made for inveterated dislocation during *the same period* For patients over 40 years of age conservative treatment can be recommended for gr III injuries

1972 Telhag & Gudmundson 1972), GAG (Collins & McElligott 1960, Mankin & Lippiello 1970) and collagen (Repo & Mitchell 1971), changes which are regarded as signs of repair

The investigation showed that the concentration of DNA in joint cartilage is significantly reduced in advanced osteoarthritis Mankin et al (1971) have, however shown that the concentration of DNA does not change significantly with advancing degeneration The reason why the results were different in our investigation might be due to the fact that we studied only cartilage with advanced osteoarthritis The synthesis of DNA per amount of tissue was significantly decreased but significantly increased per amount of DNA This result is in agreement with earlier observations in human hips with osteoarthritis (Mankin & Lippiello 1970) in rabbit knee joints (Telhag & Gudmundson 1972) and autoradiographically demonstrated increased uptake of ³H thymidine in degenerated joint cartilage from man (Mankin & Lippiello 1970 Hulth et al 1970) and animals (Telhag 1972) The concentration of RNA in advanced osteoarthritis was significantly reduced in the investigation Telhag & Gudmundson (1972) have shown that the concentration of RNA is unchanged in degenerated cartilage from the rabbit In the latter investigation however cartilage was taken from the entire rabbit knee joint i e the specimens examined consisted of a cartilage in various stages of degenerative joint disease The synthesis of RNA was significantly increased per amount of DNA In earlier investigations RNA synthesis has been described as reduced in the dog (Mankin & Lang 1967) and rabbit (Telhag & Gudmundson 1972) and unchanged in man (Mankin & Lippiello 1970 Since there is a constant relationship between the DNA concentration and the number of cells in the tissue the investigation shows that the remaining chondrocytes in the markedly degenerated cartilage are metabolically more active than those in normal cartilage

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into two equal pieces and rinsed free of blood The material was weighed (wet weight) The specimens were immediately placed in 10 ml Eagle's solution (37° C) containing 50 μCi tritiated thymidine or 50 μCi tritiated uridine and shaken for an hour and a half After washing in physiologic saline solution, the pieces were placed in a mortar and covered with liquid nitrogen and pulverized It was then homogenized in 5 ml of 10 per cent TCA (trichloro acetic acid) and the acid soluble nucleotides were separated by centrifugation and washed twice, each time with 5 ml of the same solvent The insoluble residue was treated with 5 ml of 0 3 M potassium hydroxide for 18 hours at 37° C to hydrolyze RNA which was thereby brought into solution The solution was adjusted to pH 7 by addition of 70 per cent perchloric acid An equal volume of 5 per cent TCA was added to the neutral solution This resulted in precipitation of protein and DNA, which were separated from the solution by centrifugation and washing of the precipitate three times with 5 ml of 5 per cent TCA

RNA and DNA in the separated fractions were determined with the orcinol (Mejbaum 1939) and the Ceriotti procedures (Ceriotti 1952), respectively The separation of RNA and DNA was checked in all experiments by applying both reactions to the RNA as well as to the DNA fraction Each sample was assayed separately for radioactivity (^{3}H thymidine or ^{3}H uridine) after suspension in 10 ml of Instagel (Packard), using a two channel Packard Tri Carb liquid scintillation spectrometer The results were recorded as counts per milligram of wet weight per minute

RESULTS

The DNA concentration was significantly reduced in the degenerated cartilage The RNA concentration was also significantly reduced in the degenerated cartilage in relation to the tissue content Relative to the content of DNA, the RNA concentration was increased in degenerated cartilage, but not significantly (Table 1)

The DNA synthesis (incorporation of ^{3}H-thymidine) was significantly reduced in the degenerated cartilage in relation to the tissue content, but significantly increased relative to the content of DNA The synthesis of RNA (incorporation of ^{3}H-uridine) was significantly increased in degenerated cartilage in relation to the content of DNA and unchanged in relation to the content of tissue and RNA (Table 2)

DISCUSSION

Adult joint cartilage was formerly regarded as a tissue with relatively little metabolic activity Research during the last few decades has, however, shown that degenerative changes of the cartilage are accompanied by an increased synthesis of DNA (Crelin & Southwick 1960, 1964, Mankin & Lippiello 1970, Telhag

Table 1 Comparison of quantities of DNA and RNA in osteoarthritic and control articular cartilage

Cartilage	γDNA/mg (M ± SD)	γRNA/mg	γRNA/γDNA
Control	2 2 ± 0 8	14 8 ± 7 4	7 8 ± 5 8
Osteoarthritic	1 0 ± 0 3	8 9 ± 3 9	10 1 ± 4 2
P	> 0 001	0 01 > p > 0 001	0 2 > p > 0 1

Table 2 Comparison of synthesis of DNA and RNA in osteoarthritic and control articular cartilage

Cartilage	cpm DNA/mg	cpm DNA/γDNA	cpm RNA/mg	cpm RNA/γDNA	cpm RNA/γRNA
Control	49 7 ± 14 0	24 1 ± 13 2	211 ± 166	102 ± 89	8 2 ± 7 9
Osteoarthritic	33 8 ± 13 6	44 0 ± 29 5	203 ± 98	210 ± 96	13 9 ± 8 4
P	0 05 > p > 0 01	0 05 > p > 0 01		0 05 > p > 0 01	0 2 > p > 0 1

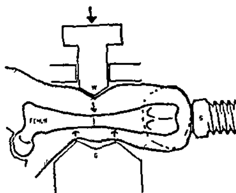


Figure 1 Standardized left femoral fractures were obtained by three point loading of the thigh between wedge (W) and groove (G) A constant level above the flexed knee joint was ensured by the screw (S)

Mean weight at the start of the experiment was 187 g with S D = 8 g

A closed standardized mid diaphyseal fracture of the left femur (Figure 1) was made under [illegible]

[illegible] pension Merck Sharp & Dohme Haarlem, The Netherlands) and placebo (Vehiculum Indocid suspension MSD) was given by stomach tube in doses of 1 ml once daily The resultant dosage of indomethacin was about 2 mg/kg/day depending on the exact weight of the animal The first dose was given immediately following fracturing of the left femur and the medication was continued until sacrifice of each animal

Sixty-one animals were used for extensometric measurements and 60 animals for bending strength testing of the fractured femurs on days 6, 9 12 18 and 24 respectively after fracture (Table 1) Three animals in the placebo treated group were excluded from the bending strength experiment one animal died accidentally during the experiment, in one the fracture was in the wrong place and in one animal the callus tumour was unintentionally injured during dissection *Radiological examination* of the fractured limbs was made on 89 of the animals, randomly selected A total of eight animals was used for histological study of the fracture healing on days 9 12, 18 and 24 of the experiment

At sacrifice, blood was collected in heparinized tubes by cannulation of the inferior caval vein during laparotomy under ether anaesthesia After having reached room temperature, the blood was centrifuged for 30 minutes at 150 × *g* Plasma samples were collected and stored at —20° C until spectrofluorometric indomethacin analysis (Gribnau et al 1973) was performed The animals were killed by severing of the aorta

Front and side radiographs were made of the fractured limb either on the day before sacrifice *or immediately* after exarticulation of the limb at the hip joint Measurements were made on the lateral view radiographs as illustrated in Figure 2 The ventral angulation of the distal fragment relative to the proximal one was measured to the nearest 5° using a protractor The distance between the fracture line and the knee joint was measured to the nearest millimetre

The fractured femur with the callus tumour was dissected free of soft tissue The specimens to be used for mechanical strength testing were kept wrapped in moist 0 9 per cent saline dressings at room temperature until tested The testing was done within 2 hours after the dissection

To assess the load deformation characteristics, the equipment illustrated in Figure 3 was used. Both ends of the femur preparation were clamped in a hydraulic strength tester (Lorentzen & Wettre *tensile strength tester type 7 1/1*, AB Lorentzen & Wettres Maskinaffär Stockholm Sweden) fitted with a strain gauge (HBM Kraftaufnehmer Type U 1 Hottinger Baldwin

Table 1 Methods of investigation and number of rats in the different groups

Experimental methods	Placebo			Indomethacin			Total	
	start	end	x ray	start	end	x ray	start	included in material
Extensometric	31	31	19	30	30	18	61	61
Bending momentum	30	27	22	30	30	24	60	57
Histology	4	4	3	4	4	3	8	8
Total	65	62	44	64	64	45	129	126

Acta orthop scand 47, 588-599, 1976

EFFECT OF INDOMETHACIN ON FRACTURE HEALING IN RATS

JOHANNES RØ*, EINAR SUDMANN & PER F. MARTON

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The healing of closed, non immobilized femoral fractures in rats was seriously impaired by indomethacin given orally at a dose of 2 mg/kg daily The fracture haematomas were larger and disappeared later in the animals receiving indomethacin Mechanical strength testing of fracture healing showed that maximal tensile strength elastic stiffness and maximal bending moment between fragments were significantly diminished in the indomethacin treated animals Radiological examination showed a smaller amount of mineralized callus and a more pronounced angulation between the fragments in these animals than in the placebo treated ones Histological examination showed bridging between the fragments by callus tissue 24 days after fracture in placebo-treated animals, whereas indomethacin treatment was followed by histological findings resembling those seen in early pseudarthrosis development

Key words anti inflammatory agents, bone, callus, fractures fractures non union indomethacin, pseudarthrosis, rats

Accepted 18 viii 76

Earlier reports dealing with the effect of potent nonsteroidal anti-inflammatory drugs on fracture healing have mainly been concerned with short-term therapy used to alleviate the immediate post-traumatic or postoperative reaction (Connell et al 1961, Allgower et al 1963, Penners 1968, Eschberger 1973) No adverse effects on fracture repair have, to the authors' knowledge, been reported It has recently been shown, however, that indomethacin inhibits the healing of mechanical lesions in heterotopic bone in rabbit ear chambers Furthermore, it has been postulated that these findings are of relevance also for the healing of fractures in orthotopic bone (Sudmann 1975)

The present study was undertaken to assess the effect of indomethacin on the healing of non-immobilized fractures of rat femur

MATERIAL AND METHODS

A total of 129 male adolescent Wistar Møllegaard albino rats, divided into two weight matched groups, were given indomethacin ($n = 64$) and placebo ($n = 65$), respectively

* Dr Rø died suddenly in April 1976 after the completion of this paper

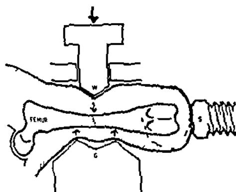


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Indomethacin suspension 0 4 mg/ml (1 1 mmol l) (diluted from Indocid commercial suspension Merck Sharp & Dohme Haarlem The Netherlands) and placebo (Vehiculum Indocid suspension MSD) was given by stomach tube in doses of 1 ml once daily The resultant dosage of indomethacin was about 2 mg/kg/day depending on the exact weight of the animal The first dose was given immediately following fracturing of the left femur and the medication was continued until sacrifice of each animal

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Accepted 18.viii.76

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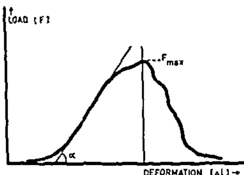


Figure 4 Schematic load deformation curve as obtained by testing femur callus specimens F_{max} = maximal load = maximal tensile strength Tan (a) = elastic stiffness

Decalc (Bethlehem Trading Gothenburg Sweden) each femur with its callus tumour was transsected in a sagittal plane along its long axis After being photographed the medial half of each preparation was embedded in paraffin Histological sections were cut at 6 μm and stained with haematoxylin/eosin

Statistical significances were evaluated by the Wilcoxon rank sum test (Wilcoxon 1947) and the Wilcoxon Van Elteren block test for grouped data (Høyland & Walløe 1975) Differences were considered significant when $2\alpha < 0.05$ Unless otherwise stated results are given as medians ± one absolute deviation

RESULTS

There was no significant difference in weight gain between the indomethacin treated and placebo-treated groups The rats tolerated the fracture well, both groups resuming full activity in a couple of days

Macroscopic examination

Measurement of the distance between the fracture and the knee joint (Figure 2) was made in 101 animals, randomly selected The mean distance was 13 4 mm with SD = 1 3 mm

During dissection of the fracture area, several distinctive features were noted In the placebo-treated animals, a well-developed callus tumour produced good connection between the fragments as early as 6 days after fracture, and only small remnants of the fracture haematoma could be seen embedded in the callus tissue In contrast, the connection between the fragments in the indomethacin-treated animals was less stable, and large fracture haematomas were, as a rule, encountered until 12 days after fracture These were thin-walled and fluctuating, and contained thin, dark red fluid

Firm fracture union was observed 18 to 24 days after fracture in the control animals, whereas most of the fractures in the indomethacin-treated animals

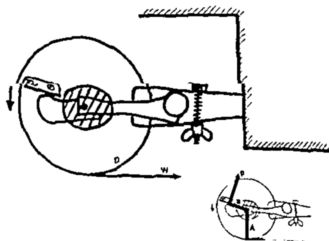


Figure 5 Bending moment measuring device The disc (D) is turned by pulling the wire (W), connected to the hydraulic tensile strength tester via the strain gauge Insert (right) shows that the moment measured (P A) equals the moment needed to bend the distal femur fragment ventrally relative to the proximal fragment (p a)

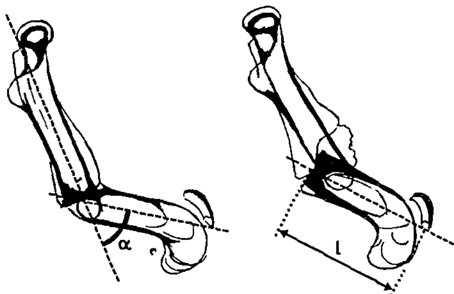


Figure 2 Measurements made on lateral view radiographs α ventral angulation of the distal fragment relative to the proximal one (left) l distance between the fracture line and the knee joint (right)

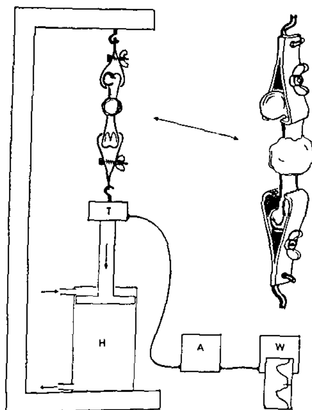


Figure 3 Equipment to assess the load deformation relationship Tensile force is exerted by the hydraulic cylinder (H) measured by the load transducer (T) and recorded by the writer (W) via a signal amplifier (A)

Messtechnik, Darmstadt, W Germany) connected via an amplifier (HBM Messverstärker KWS/T 5) to a recorder (Gould Brush 220 writer Gould Inc Instruments Systems Division Cleveland Ohio USA) The equipment was calibrated with known weights before use The load was recorded continuously during constant rate elongation (0 4 mm/s) Maximal tensile strength and elastic stiffness were calculated from the graphs (Figure 4)

Bending strength testing was done by measuring the moment needed to bend the distal femur fragment ventrally relative to the proximal fragment (Rø in preparation) The proximal end of the femur preparation was clamped immediately above a horizontal disc mounted on a vertical axis (Figure 5), the centre of the callus tumour situated in the extension of this axis The disc could be turned by pulling a thin and flexible steel wire attached to the circumference of the disc The other end of the wire was connected to the plunger of the hydraulic tensile strength tester via the strain gauge The torque was conveyed to the distal femur fragment by means of a vertical cam mounted on the disc The force used was recorded continuously during a 90° turn of the disc at a speed of 6°/s This procedure usually caused the callus tumour to break thus each femur preparation could be measured only once

The femur preparations to be used for histological study were fixed in buffered formole (Vittali 1970) Following decalcification in

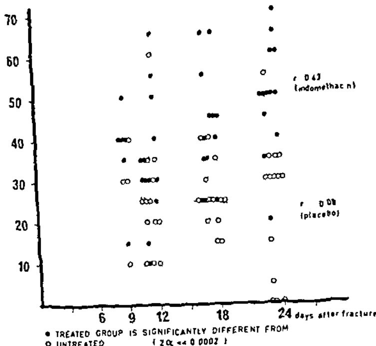


Figure 7 Scatter diagram of the angles between femur fragments on lateral view radiographs (see Figure 2 a)

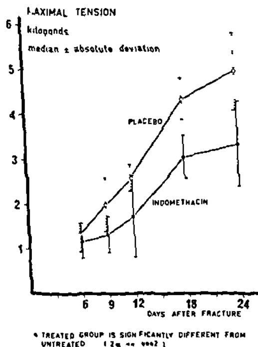


Figure 8 Maximal tensile strength of femur fractures

Mechanical strength testing

Both the maximal tensile strength (Figure 8) and the elastic stiffness (Figure 9) were significantly lower throughout the experiment in the indomethacin-treated animals than in the placebo group (Table 3) The maximal moment required to bend the distal fragment ventrally relative to the proximal fragment was found to be significantly lower in the indomethacin-treated rats on days 9 and 12 after fracture (Figure 10, Table 3), whereas on days 18 and 24 after fracture no significant difference was found between the groups

Pathological anatomy

Macroscopic examination of the transsected decalcified femur preparations showed in all the placebo-treated animals compact callus tumours without any visible central cavity Indomethacin-treated animals, however, had at all times sampled a central, transverse, slit

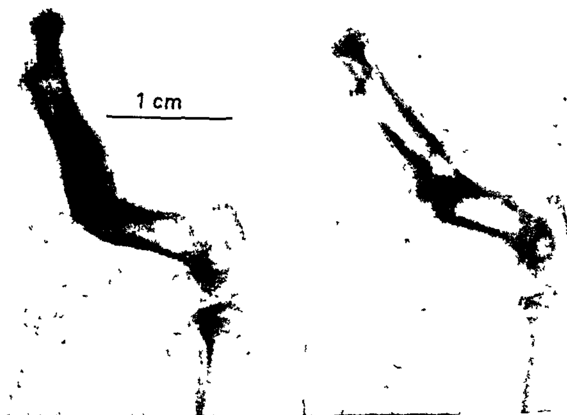


Figure 6 Lateral view radiographs of fractured femurs 24 days after fracture There is a smaller amount of mineralized callus, and the angulation between the fragments is more pronounced in the indomethacin-treated animal (left) than in the placebo-treated animal (right)

were still unstable at the end of the experiment Broad cartilaginous collars around both fracture ends were found in these animals

Table 2 Ventral angulation of the distal femur fragments relative to the proximal fragments as seen on lateral view radiographs (Median ± 1 absolute deviation)

	n	Degrees
Placebo	44	25 0 ± 10 1
Indomethacin	45	40 0 ± 12 0
	89	

The difference between the groups is highly significant ($2\alpha < 0\ 0002$)

X-ray examination

Radiological signs of continuity between the fragments, while present in the control animals, were scarce in the indomethacin-treated animals Signs of callus mineralization appeared later and were less pronounced in the indomethacin-treated than in the placebo treated animals The angle between the longitudinal axes of the fragments in lateral view (Figure 2) was larger in the indomethacin treated group (Figure 6, Table 2) This difference between the two groups was highly significant ($2\alpha < 0\ 0002$) A scatter diagram of the individual values (Figure 7) shows that this angle tended to increase with time after fracture in the indomethacin treated animals (linear *correlation coefficient* $r = 0\ 43$), whereas no such relationship was discernible in the placebo treated group of rats ($r = \quad 0\ 08$)

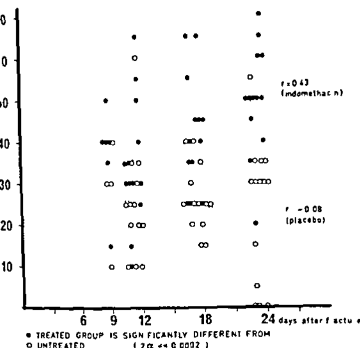


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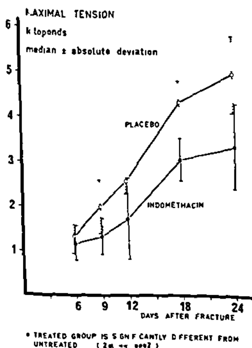


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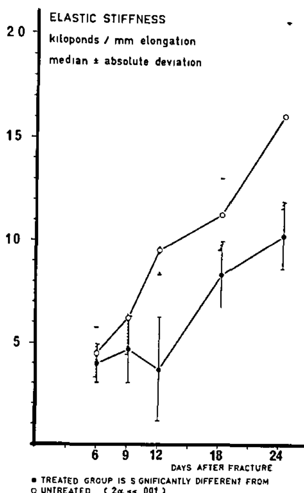


Figure 9 Elastic stiffness of femur fractures

like cavity between the ends of the fracture fragments (Figure 11) In preparations taken on days 9 and 12, this cavity was lined by irregular, fuzzy walls which on days 18 and 24 were seen to be smooth and lined by a cartilage-like tissue

Histological examination of the femur specimens from indomethacin-treated animals showed *at all stages of healing* a lesser degree of osteoid and bone callus formation than did control specimens from the placebo-treated animals At 24 days, newly formed cartilage and bone in the placebo treated animals bridged the fragments (Figure 12 b), whereas no such bridging had taken place in the indomethacin treated animals

The slit-like cavity between the ends of the femur fragments of indomethacin-treated animals was lined by fibrous tissue and fibrin on days 9 and 12 Later this cavity became smooth-walled by organization of the fibrous tissue and by local formation of cartilage, on days 18 and 24 closely resembling pseudarthrosis formation (Figure 12 a)

Indomethacin analysis

Plasma levels of indomethacin were determined in 48 randomly selected animals that were killed 3 to 21 hours after the last drug administration (Table 4) The highest indomethacin concentrations were found 6 hours after drug administration and were in the range 3 9 8 5 μg/ml with a median of 6 2 μg/ml From 16 to 21 hours after drug administration

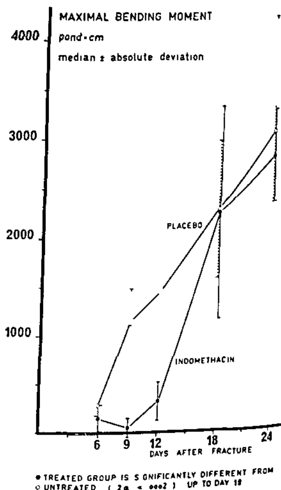


Figure 10 Maximal moment required to bend distal fragment ventrally with respect to proximal fragment

Table 3 Results of mechanical testing of fracture healing in rats receiving placebo (P) or indomethacin 2 mg/kg/day (I) (Median ± 1 absolute deviation)

Days after fracture	Extensometric testing						Bending moment (pond cm)			
	Maximal tension (kp)				Elastic stiffness (kp/mm)					
	n	P	*n*	I	P	I	*n*	P	*n*	I
6	6	1 3(± 0 42	6	1 19 + 0 40	0 46 ± 0 12	0 40 ± 0 09	6	289 + 112	6	146 ± 141
9	6	2 03 ± 0 62	6	1.36 ± 0 41	0 62 ± 0 18	0 $7 ± 0 17	4	1155 ± 329	6	4/4* ± 102
12	6	2 60 + 0 29	6	1 74 ± 0 91	0 96 ± 0 12	0 37* ± 0 25	5	1455 + 446	(	311* ± 208
18	6	4 36 ± 0 46	6	3 07* ± 0 49	1 13 ± 0 18	0 84* ± 0 17	6	2283 ± (96	6	2246 ± 1080
24	7	4 9ɔ + 0 85	6	3 36* + 0 95	1 62 ± 0 45	1 03 ± 0 16	(	3060 ± 1164	6	2810 ± 472
WAF				$\overset{*}{2\alpha} < 0\ 0002$		$\overset{*}{2\alpha} < 0\ 0002$				$\overset{*}{2\alpha} \simeq 0\ 002$

WAF Wilcoxon Van Elteren test for grouped data
* Indomethacin treated group significantly different from placebo-treated group ($2\alpha < 0\ 0a$)

the levels were found to be decreasing from 1 4 µg/ml (range 1 3–1 6 µg/ml) to 1 0 µg/ml (range 0 4–1 6 µg/ml)



Figure ... c n ... an mal ... l nc ... tarr u ... in lome ... ru fracture The placebo treat ... el fracture was clinically stable

DISCUSSION

The present investigation indicates that an oral indomethacin dosage of 2 mg/kg/day seriously impairs the healing of closed non immobilized femoral fractures in rats Such fractures usually unite within 3–4 weeks (Hulth & Olerud 1964, Lindholm et al 1970)

The dose of indomethacin used in this investigation is within the limits of tolerance for rats (Phelps et al 1968) An anti inflammatory action is observed in rats with as small a dose as 0 015 mg/kg/day in acute inflammation (Phelps et al 1968) Apparently higher doses of indomethacin are required to obtain inhibition in models of chronic inflammation, as it has been claimed that a dose of 0 1 mg/kg/day will enhance the collagen synthesis in cotton pellet granulomas in the rat (Kulonen & Potila 1975) According to Winter (1965) indomethacin in a dose of 2 mg/kg/day, which is the dose chosen for the present investigation produces between 30 and 40 per cent inhibition in the cotton pellet rat granuloma test

It is desirable that the conclusions drawn from these experiments on autopsy specimens should reflect the properties of the fracture healing tissues *in vivo* The mechanical strength of frac

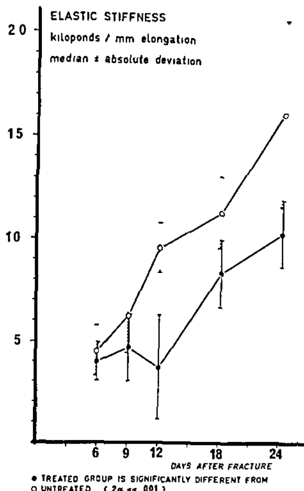


Figure 9 Elastic stiffness of femur fractures

like cavity between the ends of the fracture fragments (Figure 11) In preparations taken on days 9 and 12, this cavity was lined by irregular, fuzzy walls which on days 18 and 24 were seen to be smooth and lined by a cartilage-like tissue

Histological examination of the femur specimens from indomethacin-treated animals showed at all stages of healing a lesser degree of osteoid and bone callus formation than did control specimens from the placebo treated animals At 24 days, newly formed cartilage and bone in the placebo-treated animals bridged the fragments (Figure 12 b), whereas no such bridging had taken place in the indomethacin-treated animals

The slit-like cavity between the ends of the femur fragments of indomethacin-treated animals was lined by fibrous tissue and fibrin on days 9 and 12 Later this cavity became smooth-walled by organization of the fibrous tissue and by local formation of cartilage, on days 18 and 24 closely resembling pseudarthrosis formation (Figure 12 a)

Indomethacin analysis

Plasma levels of indomethacin were determined in 48 randomly selected animals that were killed 3 to 21 hours after the last drug administration (Table 4) The highest indomethacin concentrations were found 6 hours after drug administration and were in the range 3 9–8 5 μg/ml with a median of 6 2 μg/ml From 16 to 21 hours after drug administration

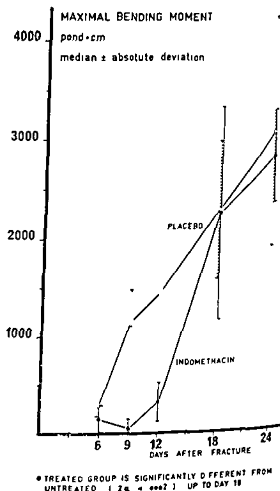


Figure 10 Maximal moment required to bend distal fragment ventrally with respect to proximal fragment

Table 3 Results of mechanical testing of fracture healing in rats receiving placebo (P) or indomethacin 2 mg/kg/day (I) (Median ± 1 absolute deviation)

Days after fracture	Extensometric testing						Bending moment (pond cm)			
	Maximal tension (kp)				Elastic stiffness (kp/mm)					
	n	P	*n*	I	P	I	*n*	P	*n*	I
6	6	1 36±0 42	6	1 19 ±0 40	0 46±0 12	0 40 ±0 09	6	289± 112	6	146 ± 141
9	6	2 03±0 62	6	1 36*±0 41	0 62±0 18	0 47 ±0 17	4	1155± 329	6	44*± 102
12	6	2 60±0 29	6	1 74 ±0 91	0 96±0 12	0 37*±0 25	5	1455± 446	6	314*± 208
18	6	4 36±0 46	6	3 07*±0 43	1 13±0 18	0 84*±0 17	6	2283± 696	6	2246 ±1080
24	7	4 95±0 85	6	3 36*±0 95	1 62±0 45	1 03 ±0 16	6	3060±1164	6	2810 ± 472
WVE				$^{*}2\alpha < 0.0002$		$^{*}2\alpha < 0.0002$				$^{*}2\alpha = 0.002$

WVE Wilcoxon Van Elteren test for grouped data
* Indomethacin treated group significantly different from placebo treated group ($2\alpha < 0.05$)

the levels were found to be decreasing from 1 4 µg/ml (range 1 3–1 6 µg/ml) to 1 0 µg/ml (range 0 4 1 6 µg/ml)



Figure 11 Fractured left femur from indomethacin treated (left) and placebo treated (right) animals 15 days after fracture sagittally sectioned Note slit shaped interfragmental cavity (arrows) lined with cartilaginous tissue in the indomethacin treated fracture The placebo treated fracture was clinically stable

DISCUSSION

The present investigation indicates that an oral indomethacin dosage of 2 mg/kg/day seriously impairs the healing of closed non-immobilized femoral fractures in rats Such fractures usually unite within 3–4 weeks (Hulth & Olerud 1964, Lindholm et al 1970)

The dose of indomethacin used in this investigation is within the limits of tolerance for rats (Phelps et al 1968) An anti inflammatory action is observed in rats with as small a dose as 0 015 mg/kg/day in acute inflammation (Phelps et al 1968) Apparently higher doses of indomethacin are required to obtain inhibition in models of chronic inflammation, as it has been claimed that a dose of 0 1 mg/kg/day will enhance the collagen synthesis in cotton pellet granulomas in the rat (Kulonen & Potila 1975) According to Winter (1965) indomethacin in a dose of 2 mg/kg/day, which is the dose chosen for the present investigation, produces between 30 and 40 per cent inhibition in the cotton pellet rat granuloma test

It is desirable that the conclusions drawn from these experiments on autopsy specimens should reflect the properties of the fracture healing tissues *in vivo* The mechanical strength of frac-



Figure 12 Photomicrographs of detail from fracture site indomethacin treated (a) and placebo treated (b) animal 24 days after fracture Inserts show the localization of the areas reproduced (arrows) with reference to Figure 11 (Haematoxylin eosin)

Table 4 Plasma levels of indomethacin at time of sacrifice

Hours after last drug administration	Indomethacin concentration µg/ml Median ± 1 absolute deviation
3	3 7 ± 1 6
6	2 2 ± 1 5
16	1 4 ± 0 1
18	1 4 ± 0 3
19	1 4 ± 0 4
19 5	1 3 ± 0 4
20	0 9 ± 0 3
21	1 0 ± 0 4

ture repair has often been evaluated in terms of maximal tensile strength To reach this value, however it is usually necessary to exceed the range of elastic deformation When the range of plastic deformation is entered, the deformation causes lasting damage to the tissues tested Consequently, it appears to be most appropriate to perform measurements within the range of elastic deformation Within this range, measurement of the elastic stiffness has been recommended (Viidik 1973) This is taken as the slope of the linear part of the load-deformation curve (Figure 4)

Since the forces used in tensile testing systems are more or less the opposite of the forces acting *in vivo* (i e muscle tone and weightbearing), such models appear to have limited relevance as tests of fracture healing As a consequence, a method was developed to obtain measurements of the capacity of the fractured femurs to resist bending (Ro, in preparation) These bending moment measurements were included in the present study

as a supplement to the tensile tests, and served to demonstrate the considerable difference in fracture stability between the indomethacin-treated and placebo-treated animals on days 9 and 12 after fracture (Figure 10) On days 18 and 24 the large cartilaginous collars which developed around the fracture ends in the indomethacin-treated animals probably were an obstacle to the bending procedure This may explain why the bending moment measurements were not significantly different between the groups on these days

The radiological and mechanical tests demonstrated that the fracture repair strength was considerably lowered by indomethacin administration Furthermore, the changes found in the macroscopic and histological examinations closely resembled those seen in pseudarthrosis formation This finding is quite remarkable, since it indicates that indomethacin not only delays the fracture healing process, but causes the process of repair to be qualitatively altered It is thus probable that while new bone is produced in the placebo-treated animals, connective tissue and cartilage dominate at the fracture site of the indomethacin-treated animals This may well account for the considerable differences in mechanical properties of the fractures in indomethacin and placebo-treated animals It should be noted, however, that it would be necessary to continue the study for a considerable length of time in order to assess whether pseudarthrosis would occur Lindholm et al (1970) have shown that abnormal mobility can be maintained in tibial fractures in rats for as long as 48 days after fracture by daily manipulation under narcosis When left undisturbed, however, the resultant large cartilaginous callus tumour will mineralize and proceed to consolidation in a very short time A similar effect might be encountered after discontinuation of indomethacin

The fracture trauma is followed by an aseptic inflammation which initiates the process of fracture repair The effect of indomethacin demonstrated in the present study may, consequently, be caused by an interference with the inflammatory process If this is so, other potent anti-inflammatory drugs may also affect fracture healing in this way

It has been postulated that the effects of the nonsteroidal anti inflammatory drugs are due to inhibition of the prostaglandin synthetase activity (Vane 1971). The role of prostaglandins in bone formation has not been fully established, but it has been reported that prostaglandin E. inhibits bone collagen synthesis dose dependently (Raisz & Koolemans Beynen 1974) Indomethacin dosage inhibited bone callus production in the present study, whereas increased bone formation would have been expected if this drug influenced fracture healing through prostaglandin E. synthetase inhibition

Collagen synthesis in experimental rat granulomas is inhibited by indomethacin in the dose used in the present study (Winter 1965) It has recently been shown, however, that collagen synthesis studied *in vitro* is greater in fracture callus tumour tissue from rats given indomethacin 2 mg/kg/day than in corresponding tissue from placebo-treated animals (Rø & Sander, in preparation) It is thus not probable that indomethacin delays the fracture healing process by inhibiting the callus collagen synthesis Since osteoid and mineralized bone tissue formation were sparse in indomethacin-treated animals both in the present study and in a preceding study (Sudmann 1975), these findings suggest that the effect of indomethacin on fibroblastic activity is qualitatively different from its effect on primitive, disordered osteoblastic activity

Large fracture haematomas were observed in the indomethacin treated ani-



Figure 12 Photomicrographs of detail from fracture site, indomethacin-treated (a) and placebo treated (b) animal, 24 days after fracture Inserts show the localization of the areas reproduced (arrows) with reference to Figure 11 (Haematoxylin-eosin)

Table 4 Plasma levels of indomethacin at time of sacrifice

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19 5	1 3 ± 0 4
20	0 9 ± 0 3
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ture repair has often been evaluated in terms of maximal tensile strength To reach this value, however, it is usually necessary to exceed the range of elastic deformation When the range of plastic deformation is entered, the deformation causes lasting damage to the tissues tested Consequently, it appears to be most appropriate to perform measurements within the range of elastic deformation Within this range, measurement of the elastic stiffness has been recommended (Viidik 1973) This is taken as the slope of the linear part of the load-deformation curve (Figure 4)

Since the forces used in tensile testing systems are more or less the opposite of the forces acting *in vivo* (i e muscle tone and weightbearing), such models appear to have limited relevance as tests of fracture healing As a consequence, a method was developed to obtain measurements of the capacity of the fractured femurs to resist bending (Rø, in preparation) These bending moment measurements were included in the present study

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mals This is in accord with the anticoagulant effect of nonsteroidal anti-inflammatory drugs, and most of these drugs furthermore induce a moderate degree of fibrinolysis *in vitro* (Famaey et al 1975) Since the use of anticoagulants has been reported to inhibit fracture healing (Stinchfield et al 1956), and the fracture haematoma according to Ham & Harris (1971) is thought to be an obstacle to the fracture healing process, these factors may have contributed to the delayed fracture healing in the present study

A possible relationship between indomethacin medication and joint destruction has been reported (Coke 1967, Arora 1968, Rubens-Duval et al 1970, Desproges-Gotteron et al 1971, Solomon 1973, Hauge 1975) It has been presumed that this effect is primarily brought about by the analgetic action of the drug, the state of diminished sensibility predisposing to trauma in the subarticular bone Sudmann (1975) has recently postulated that inhibition of the healing of spontaneous microfractures in the subchondral cancellous bone in weight-bearing joints may be of importance in the pathogenesis of the indomethacin-induced arthropathy This contention is supported by the present study, provided that indomethacin when given in clinical doses interferes with the normal fracture healing in man as it does in rats in the dose used here

ACKNOWLEDGEMENTS

The authors are grateful to Per Ludvigsen engineer, Biomechanical Laboratory Sophies Minde Orthopaedic Hospital for assistance in assembling the tensile strength recording equipment Gunnar Woxholt M D Department of Radiology, Rikshospitalet for radiological advice Merck Sharp & *Dohme*, Norway for kindly supplying indomethacin suspension and placebo and making arrangements for indomethacin analysis, F W J Gribnau Nijmegen University the Netherlands in whose laboratory the indomethacin assay was performed and Dr Alexander Malthes Fund and Norsk Forening til Kreftens Bekjempelse for financial support

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Table 1 Longitudinal growth of the right proximal tibia in microns per day in normal female rats (values from Stenström et al 1976)

Age in days	n	Growth rate M ± SD	
30–32	10	326	14
38–40		261	33
	10	–16	12 a
40–42		247	33
45–47	10	218	24 b
50–52	12	194	11
60–62	16	137	12
70–72	12	96	14
80–82	17	75	6
100 102	19	39	4
140–142	10	18	4

a Difference between 40–42 and 38–40 days of age
b Normal value calculated from 40–42 and 50–52 days of age
n = number of animals
M = mean value
SD = standard deviation

fracture intervals the longitudinal growth rate in proximal tibia and distal radius was determined by the tetracycline method The animals were given oxytetracycline (Terramycin®) 5 mg per kg body weight i p on two or three occasions with two days interval between before being killed (Tables 2–4) They were sacrificed with ether one day after the last injection of oxy- ...

determination of the growth rate, according to an earlier described method (Hansson 1967, Hansson et al 1972) The results from a simultaneous investigation which determined the growth rate in proximal tibia in normal animals (Table 1) were used for comparison (Stenström et al 1976)

RESULTS

Effect on growth rate in proximal tibia (Tables 1–4, Figures 1–3)

Femoral fracture During the first days after the fracture, a difference was noted in the growth rate in the proximal tibia It amounted to 16 µm per day This reduced slowly and ceased 10 to 20 days after the fracture

The difference in the growth rate, compared with normal growth, was shown to be caused by the growth rate on the unfractured side slowing down in the

Table 2 Longitudinal growth of the proximal tibia (right and left) in microns per day after femoral fracture (left)

Age in days	Days after fracture	n	Growth rate right M ± SD		Growth rate left M ± SD		Difference in growth rate left – right M ± SD	
38 40	2 0		258	17 (–)	258	19 (–)	0	3 (–)
		6	14	11 ( )	2	12 *		
40–42	0– 2		244	16 (–)	260	17 ( )	16	7 **
45–47	5– 7	5	228	16 ( )	238	17 ( )	10	6 *
50–52	10–12	6	204	6 (–)	210	10 **	7	6 *
60–62	20 22	6	140	19 ( )	143	21 (–)	4	2 *
70 72	30 32	5	104	8 (–)	105	8 (–)	2	5 (–)
100 102	60–62	7	38	2 ( )	38	3 (–)	0	1 (–)

Statistical analysis (Student s t test)
Right and left side of fracture groups compared with normal group (Table 1)
Difference between fractured and unfractured side in fracture groups
Difference between 40–42 and 38–40 days of age in fracture groups compared with normal group Table 1

n = number of animals
M = mean value
SD = standard deviation
*** = $p < 0.001$
** = $0.001 < p < 0.01$
* = $0.01 < p < 0.05$
(–) = $p > 0.05$

Acta orthop scand 47, 600 606 1976

EFFECT OF FRACTURE ON LONGITUDINAL BONE GROWTH IN RATS

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The growth rate in proximal tibia and distal radius in rats was investigated by the tetracycline method after femoral fracture tibiofibular fracture, and metatarsal fracture Up to 1 to 2 weeks after the fracture, a higher growth rate was recorded on the fractured side than on the unfractured side This effect occurred later after tibiofibular fracture than after femoral and metatarsal fracture, but was almost of the same size and about 8 per cent of the normal growth rate This difference in growth rate was caused partly by a general growth retardation compared with the normal growth rate, and partly by a local growth stimulation in the fractured extremity The growth retardation was pronounced after tibiofibular fracture, but was insignificant after femoral and metatarsal fracture The growth rate on the fractured side after the latter two types of fractures was higher than under normal conditions Thirty days after all types of fractures the growth rate was normal both in fractured extremity and in other growth regions

Key words bone and bones, bone lengthening fractures, growth tetracyclines

Accepted 25 ix 76

It has long been known that a fracture affects the rate of longitudinal bone growth in such a way that the growth rate increases on the fractured side compared with the other side This counteracts the shortening that often occurs during the fracture healing (for review see Guldhammer 1963, Hedstrom 1969) Usually, growth stimulation has been found only in the fractured bone (Guldhammer 1963), but others have also found some stimulation in the adjacent bones (Bertrand & Trillat 1948)

This work investigates in closer detail how the growth rate in the proximal tibia in rats is influenced by a diaphyseal fracture in femoral, tibiofibular, or in metatarsal bones The general effect on growth has also been investigated in distal radius in this study

MATERIAL AND METHODS

One hundred and five female rats of Sprague Dawley strain with known birth date were used At age 40 days a closed fracture in the femoral diaphysis in 35 animals, in the tibiofibular diaphysis in 35 and through the metatarsal bones in 35 was produced manually on the left side under ether anaesthesia The *localization* of the fracture was controlled by X ray The fractured extremity was not immobilized as immobilization is known to affect longitudinal bone growth (Sundén 1967) At different post

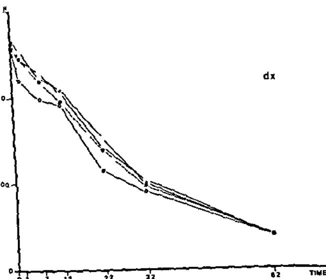


Figure 1 Longitudinal bone growth of right proximal tibia (unfractured side) in microns per day Time in days after fracture

femoral fracture
tibiofibular fracture
metatarsal fracture
normal

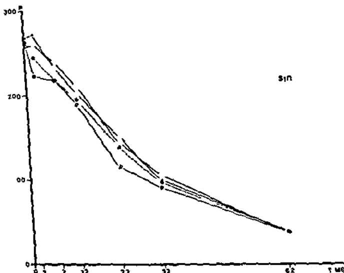


Figure 2 Longitud nal bone growth of left proximal tibia (fractured side) in microns per day Time in days after fracture For symbols see Figure 1

showed an initial growth stimulation This accounted for the difference

Effect on the growth rate in distal radius (Table 5 Figure 4)

The growth rate in distal radius was recorded in the fractured animals Mutual comparison showed that only the tibiofibular fracture gave growth retardation This was demonstrated up to 10 to 20 days after the fracture In the following period the growth rate in the various fracture groups was on the same level

DISCUSSION

The growth rate in proximal tibia can, with great reliability, be determined under experimental conditions in the rat with an error of about 5 μm (Hansson et al 1972) It has also earlier been

Table 3. Longitudinal growth of the proximal tibia (right and left) in microns per day after tibiofibular fracture (left)

Age in days	Days after fracture	n	Growth rate right M	± SD	Growth rate left M	± SD	Difference in growth rate left – right M	± SD
38–40	–2– 0		255	32 (–)	257	32 (–)	2	2 (–)
		5	–35	5 **	–33	20 *		
40–42	0– 2		220	31 (–)	223	27 (–)	3	17 (–)
45–47	5– 7	6	197	15 (–)	218	16 (–)	21	7 ***
50–52	10–12	6	191	20 (–)	189	11 (–)	–2	14 (–)
60–62	20–22	6	115	15 **	115	16 **	0	4 (–)
70–72	30–32	6	90	8 (–)	92	8 (–)	2	2 (–)
100–102	60–62	6	39	2 (–)	39	2 (–)	0	0 (–)

(For legends see Table 2.)

Table 4. Longitudinal growth of the proximal tibia (right and left) in microns per day after metatarsal fracture (left)

Age in days	Days after fracture	n	Growth rate right M	± SD	Growth rate left M	± SD	Difference in growth rate left – right M	± SD
38–40	–2– 0		265	30 (–)	267	30 (–)	2	2 (–)
		5	–11	12 (–)	6	12 **		
40–42	0– 2		254	23 (–)	272	26 (–)	18	5 **
45–47	5– 7	6	223	12 (–)	233	11 (–)	9	6 **
50–52	10–12	6	207	15 (–)	203	14 (–)	4	2 **
60–62	20–22	6	151	8 *	150	6 *	–2	3 (–)
70–72	30–32	6	98	6 (–)	99	5 (–)	0	2 (–)
100–102	60–62	6	38	1 (–)	38	1 (–)	0	1 (–)

(For legends see Table 2.)

same way as in the normal animals, *whereas the growth* rate on the fractured side, for some days, was *the same as immediately* before the fracture, which argues for a certain growth stimulation on the fractured side. In the *following period*, the growth rate on the *unfractured* side was normal, *whereas the corresponding* rate on the *fractured side* was somewhat higher *and became normal* after 10 to 20 *days*.

Tibiofibular fracture. During the first days after fracture, there was no difference in growth rate in the proximal tibia, but after a few days there was a difference of 21 μm per day with a higher growth rate on the fractured side. In the following period, the growth was the same on both the fractured and unfractured sides.

Both sides showed an initial retardation compared with normal growth which was corrected after 20 to 30 days.

Metatarsal fracture. During the first week, the result was similar to the femoral fracture, a difference in growth rate was recorded with a higher growth rate on the fractured side compared with the unfractured side.

Compared with the normal material, the unfractured side showed no growth retardation, whereas the fractured side

Table 5 Longitudinal growth of distal radius (left) in microns per day after fracture of different long bones

Age in days	Days after fracture	Femoral fracture n	M	± SD	Tibiofibular fracture n	M	± SD	Metatarsal fracture n	M	± SD
38–40	2 0		162	19		174	22 (–)		176	23 (–)
		6	–10	5	5	–32	5 ***	5	–7	9 (–)
40–42	0– 2		152	17		141	20 ( )		170	17 (–)
45–47	5– 7	5	155	14	6	126	13 **	6	141	11 (–)
50–52	10–12	6	132	5	6	107	13 **	6	132	15 (–)
60–62	20–22	6	83	14	6	75	7 (–)	6	90	5 (–)
70–72	30–32	5	66	5	6	64	11 (–)	6	63	3 (–)
100–102	60–62	7	26	3	6	26	3 (–)	6	27	2 (–)

n = number of animals
M = mean value
SD = standard deviation
*** = $p < 0.001$
** = $0.001 < p < 0.01$
* = $0.01 < p < 0.05$
(–) = $p > 0.05$

* in tibiofibular and metatarsal fracture groups compared with femoral fracture group

metatarsal fracture These findings are in good agreement with earlier results in the rabbit (Hansson 1967) which showed that a trauma of the medullary cavity of the tibia produces a relatively insignificant difference most pronounced a few days after the trauma whereas a trauma that did not affect the medullary cavity of the tibia made an immediate and significant difference in growth rate

The accumulated difference in growth rate seemed somewhat larger after femoral fracture than after tibiofibular and metatarsal fractures Also the growth stimulation seemed somewhat more prolonged but these differences were relatively small and insignificant

This investigation clearly shows that both a femoral fracture and a metatarsal fracture influence the growth of the tibia during the week immediately after the fracture This is in good agreement with the results reported by Wray & Goodman (1961) that a tibial fracture influences the growth in the femur In the latter work, however, it was found that the growth difference was not significant until the second week, but those authors used radiography which showed the accumulated difference in growth rate during the whole investigation period This accumulated difference was also greatest during the second week in our investigation

In clinical material we do not usually find an early growth difference in the femur after tibial fracture and vice versa This is probably because the radiographic determination method is rather coarse and gives the accumulated difference in growth rate and because children grow more slowly than experimental animals According to Guldhammer (1963), the growth stimulation continues up to 18 months after a fracture in a child, whereas the present investigation has shown that the growth stimulating effect is usually eliminated after 2 to 3 weeks in the rat A corresponding difference also occurs for fracture healing

An earlier work (Hansson 1967) showed that the difference in growth rate, after trauma to tibia, is caused partly by a general growth retardation of varying degree and duration, and partly by a less pronounced retardation or even

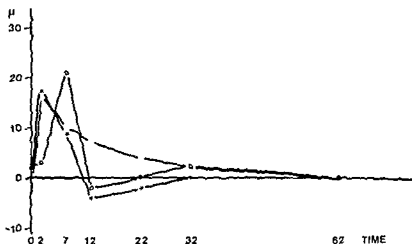


Figure 3 Difference in longitudinal bone growth between left (fractured side) and right (unfractured side) proximal tibia in microns per day Time in days after fracture For symbols see Figure 1

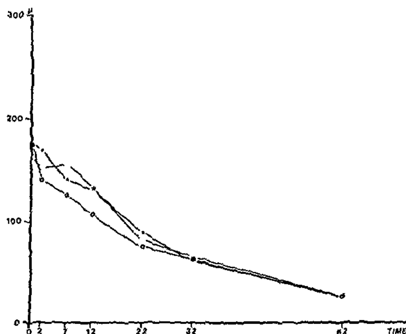


Figure 4 Longitudinal bone growth of left distal radius in microns per day Time in days after fracture For symbols see Figure 1

shown that the growth rate varies insignificantly between animals of the same strain, sex, and age (Hansson et al 1972), therefore, comparisons between different experimental animals made in this investigation are possible

The difference in growth rate between fractured and unfractured sides, as recorded on the days immediately after the fracture, reaches about 6 to 10 per cent of the normal growth rate and is relatively rapidly reduced during the next 10 days, possibly somewhat slower after femoral fracture than after the other fractures This is in good agreement with the experimental studies on rabbits concerning the effect of various types of metaphyseal and diaphyseal traumata (Hansson 1967, Hedstrom 1969) The difference in growth rate was observed after femoral and metatarsal fractures during the first days, whereas the difference after tibial fracture was not observed until a few days later This is probably associated with the fact that the diaphyseal and metaphyseal medullary vessels are damaged in the proximal tibia at tibiofibular fracture which produces another reaction pattern in the proximal tibia than after femoral and

Acta orthop scand 47 607–612 1976

HAEMOPHILIC ARTHROPATHY SURVEYED WITH WHOLE-BODY GAMMA CAMERA SCINTIGRAPHY

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A number of joints suffering from haemophilic arthropathy was studied They were surveyed clinically radiologically and with a new system of whole body gamma camera scintigraphy This radio isotopic technique provides advantages such as sensitivity speed and safety The results of the survey are presented and discussed

Key words haemophilia arthropathy whole body gamma-camera scintigraphy

Accepted 25 viii 76

Haemophilic arthropathies create a variety of problems to the clinicians as far as their diagnosis evolution and treatment are concerned The radiological methods used for the study of these arthropathies have their well known limitations while on the other hand the sensitivity of radio-isotopic techniques used for the early detection of bone lesions has been well documented Generalised articular lesions such as those observed in haemophilia have not been systematically investigated with scintigraphy

The articular lesions of haemophilic patients seen at "Vassilefs Pavlos Hospital were examined with 99 m Technetium Pyrophosphate and a new system of whole body scintigraphy was developed which combines the scintillation camera and a table which can be moved automatically The results of this examination were compared with clinical and radiological data

PATIENTS AND METHODS

Forty patients aged from 5 to 49 years were

eight suffered from haemophilia B (a severe form) (Table 1) All patients had histories of repeated haemarthroses (three or more) occurring in various joints On clinical examination there was no evidence of acute haemarthrosis

A comparative study based on clinical radiological and scintigraphic data was performed on the following joints shoulders elbows, hips knees and ankles (Table 2) The clinical data for this study consisted of a recording of the range of movement of all joints examined The recorded figures represent the percentage of the full range of movement of these joints which is rated 100 per cent

The radiological data included X rays of the joints studied which were divided into 4 groups according to the severity of articular lesions These lesions included 1) Narrowing of the joint space 2) Sclerosis 3) Cyst formation 4) Osteoporosis and 5) Destruction of Bone Architecture

a stimulation in the traumatized area A similar condition was found in this investigation, where a tibial fracture caused a general growth retardation, but locally, on the fracture side, the retardation was less pronounced compared with the normal growth rate At both femoral fracture and metatarsal fracture, however, no significant general retardation was recorded On the other hand, the growth rate in the proximal tibia of the fractured side was higher than the normal side This variation in reaction pattern at different fracture localizations and the degree of traumatization is probably vascularly conditioned

In conclusion, the results from this investigation show that the difference in growth rate after a trauma is partly due to the general growth retardation compared with the normal growth rate, and partly due to the local stimulation of the growth rate that occurs in the traumatized extremity compared with the contralateral side Both the general growth retardation and the local growth stimulation are governed by the degree of traumatization and the localization of the trauma

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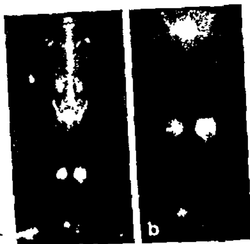




Figure 2 Scintigram of haemophilic patient a = Whole-body scanning (A-P view) A high uptake is noted in the right elbow, both knees, and right ankle b = Enlargement of the lower half of the body c = Enlargement of the knee area





Figure 3 Enlargement of the right ankle (a) and the right elbow (b)

This increased fixation varies according to the degree and extent of the lesions, and the existence of a recent haemarthrosis

Scintigraphic data were correlated with the age of the patients, the frequency of haemarthroses, and the X-rays of the joints Elbows, knees and ankles present the highest number of positive findings (Table 3). A possible explanation for this phenomenon could be that these joints have the highest incidence of lesions Shoulders and hips are less often positive, possibly because of lack of mechanical stresses of the shoulders, and because of the limited volume of haemarthroses of the hip

The results of clinical, radiological and

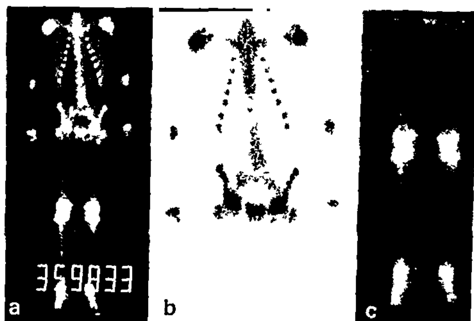


Figure 1 Scintigram of normal young subject a = Whole body scanning (A–P view) b = Enlargement of the upper half of the body c = Enlargement of the lower half of the body

Table 1 Haemophilic arthropathy surveyed with whole body gamma camera scintigraphy

Type	No	Severe	Medium
A	32	27	5
B	8	8	–
Total	40	35	5

Table 2 Haemophilic arthropathy surveyed with whole body gamma camera scintigraphy

Joints studied	(400)
Shoulders	80
Elbows	80
Hips	80
Knees	80
Ankles	80

The scintigraphic study of the skeleton was performed with a gamma camera (Dyna camera 3c Picker) combined with a system which allowed recording of whole body scintigrams for approximately 10 minutes (Omniview whole body imaging system) This system includes an automatic mobile table and an electronic control panel The gamma camera detector which is stable surveys an area of 200 × 60 cm² The control panel checks various parameters such as the dimensions of the area the dimensions of the picture the speed of movement of the table etc The pictures are recorded on a Polaroid film as well as on a video tape Play back enlargements of the areas of interest can also be produced The study of the skeleton starts three hours after intravenous administration of 5 to 10 mCi (according to age) of 99 m Technetium Pyrophosphate (Cooke & Kaplan 1972)

The patient is placed in the supine position on the table with the detector above him In this position the detector lies very close to most of the joints especially the knees and ankles which are both of great interest Figure 1 shows the whole of the skeleton and of the limited areas of interest of a normal subject

In children the growth zones present a high fixation of the tracer In the lower limbs the epiphyses look like horizontal bands The hips and shoulders present a round area of high activity In order to evaluate the images each skeletal segment is compared with its contralateral segment and the surrounding area

The absorbed dose of radioactivity for a whole body scanning is 0 05 rad per mCi while for the 15 radiographs required for the survey of the joints studied the dose is 0 52 rads

RESULTS

Haemophilic arthropathies examined with radio-isotopic techniques present a high fixation of the tracer (Figures 2 and 3)

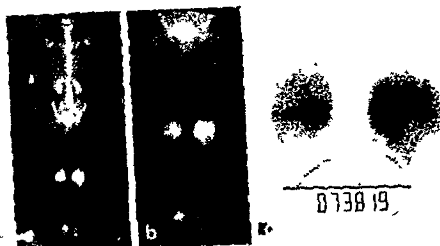


Figure 2 Scintigram of haemophilic patient a = Whole body scanning (A-P view) A high uptake is noted in the right elbow both knees and right ankle b — Enlargement of the lower half of the body c — Enlargement of the knee area

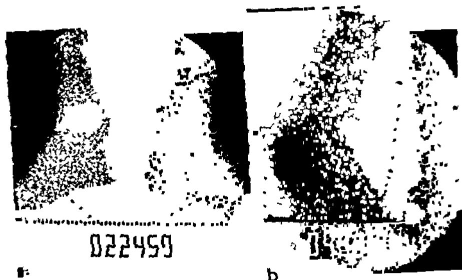


Figure 3 Enlargement of the right ankle (a) and the right elbow (b)

This increased fixation varies according to the degree and extent of the lesions and the existence of a *recent* haemarthrosis

Scintigraphic data *were correlated* with the age of the *patients* the frequency of haemarthroses, and the X rays of the joints Elbows, knees and ankles present the highest number of positive findings (Table 3) A possible explanation for this phenomenon could be that these joints have the highest incidence of lesions Shoulders and hips are less often positive, possibly because of lack of mechanical stresses of the shoulders, and because of the limited volume of haemarthroses of the hip

The results of clinical, radiological and

Table 3 Haemophilic arthropathy surveyed with whole-body gamma camera scintigraphy

Joints	Haem-arthroses	Stiffness	X-rays positive	Scinti-graphy positive
Shoulders	34	7	16	18
Elbows	57	30	24	41
Hips	27	6	12	6
Knees	64	43	54	57
Ankles	57	30	36	47
Total	239	116	142	169

scintigraphic examinations revealed scintigraphy-detected lesions in 169 joints, radiological findings in 142 joints, and 116 joints on clinical examination (with limitation of movement) Radiography, when compared with scintigraphy presents a sensitivity of 84 per cent, and clinical examination (i e limitation of movement) a sensitivity of 68 per cent

DISCUSSION

The study of our material leads to the following comments Stiff joints presented an important degree of tracer fixation which is probably due to the severity of existing bone lesions and also to some osteoporosis It was thus noted that a number of knees and ankles with no previous haemarthroses presented a high fixation of the tracer, although in these cases, the X-rays were found to be negative Mechanical reasons could probably account for this phenomenon, i e, increased stress on the load-bearing articular surfaces resulting in a local reinforcement of the trabeculae along the trajectories of the principal stresses

In young patients with a recent haemarthrosis, a high tracer fixation was noted, accompanied by negative X-rays (Figures 4 and 5) In cases of chronic haemophilic arthropathies, both scintigraphy and radiography were positive (Figures 6 and 7)

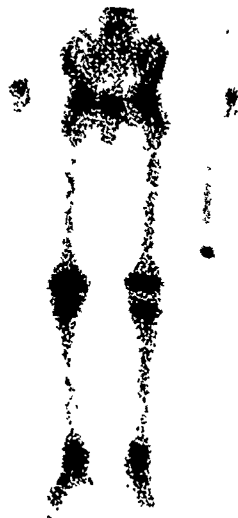


Figure 4 Scanning of the lower limbs of a young haemophiliac, showing repeated haemarthroses of the right knee and both ankles Compare the degree and appearance of the fixation in both knees

Although it is certain that chronic haemophilic lesions can be correlated with intra-articular haemorrhages, the mechanism leading to arthropathy is not clear A variety of factors should be taken into consideration such as the findings from histological material, the radiological changes, and the results from experimental studies Radio isotopes could be a valuable contribution in any morphological and dynamic study

A number of patients showing unilateral affection of the knee underwent

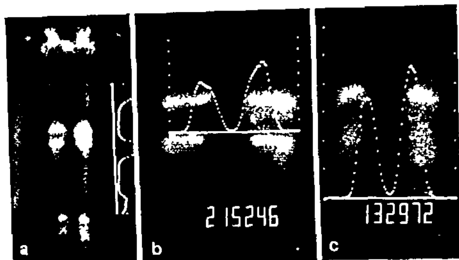


Figure 5 Scanning of the lower limbs of a young haemophiliac with repeated haemarthroses of the left knee and ankles (a) Quantitative study The uptake curve is higher in the attacked knee (b) The curve was obtained by measurement of the uptake by a mini computer Fixation curves at both ankles (c)



Figure 6 Knees and ankles of a haemophiliac with chronic arthropathy

a dynamic study of the fixation of the tracer for a period of 60 min Two areas of equal interest in the knees were chosen and with the histograms the number of counts for each knee from 1 to 5 min and 56 to 60 min was calculated The ratio of the two figures was considered as a parameter indicating the rate of tracer fixation in each knee With the study of the fixation curves (which is the subject of a current project) one could suggest that a recent haemarthrosis produces a high tracer fixation This could be the result of a reactive hypervascularization, whereas the final fixation seems to be the result of a metabolic disturbance

The advantages of the exposed method of Scintigraphic survey are its sensitivity, speed and safety As disadvantages one could point out that this method is not specific and therefore presents minimal diagnostic value, and that it does not produce detailed pictures when compared with radiography



Figure 7 Radiographs of the same patient

CONCLUSIONS

Whole-body gamma-camera scintigraphy presents valuable assets when compared with the classic methods of survey of haemophilic arthropathies In a relatively short time all involved joints can be safely assessed This survey presents great interest for the follow-up of the lesions, the prevention of relapses, and the assessment of results of treatment

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Correspondence to Ass Professor G Cambouroglou, M D, 7 Semitelou Street, Athens 611, Greece

Acta orthop scand 47, 613-618 1976

MUSCLE BLOOD FLOW AFTER AMPUTATION WITH SPECIAL REFERENCE TO THE INFLUENCE OF OSSEOUS PLUGGING OF THE MEDULLARY CAVITY

Assessed by 133 Xenon and Histamine

An Animal Experiment

CHR HANSEN LETH

The Department of Orthopaedic Surgery U Rigshospitalet Copenhagen and
The Orthopaed c Hospital Copenhagen

The muscle blood flow (MBF) in rabbits subjected to amputation of the crus was assessed by means of 133 Xenon and Histamine It was shown that after the operation the flow in the amputation stump was initially reduced MBF in the stump increased more rapidly and stayed at a higher level after closure by myoplasty than after amputation without myoplasty and it was still further stimulated after osseous plugging of the medullary cavity

Key words amputation medullary plugging muscle blood flow myoplasty 133 Xenon clearance method

Accepted 25 ix 76

After amputation the muscle blood flow in the amputation stump is essential for primary healing as well as for future function In clinical and experimental trials (Hulth & Olerud 1962, Erikson 1965 Erikson & Olerud 1966 Hansen Leth & Reimann 1972), arteriography has disclosed a hypervascularization in the amputation stump Myoplasty (Dederich 1963) as well as osteomyoplasty (Langhagel 1968) applied to the stump will further increase vascularization However arteriography is a morphological investigation method and the correlation between arteriographically demonstrated hypervascularization and muscle blood flow is uncertain

The aim of this study is to investigate the vascular reaction after amputation in rabbits, and the influence of myoplasty and osteomyoplasty, by assessment of the muscle blood flow (MBF) by means of the 133 Xenon clearance method

MATERIAL AND METHOD

Twenty six adult rabbits were amputated on the left crus Amputation was performed without myoplasty in seven cases and with myoplasty in six In thirteen animals amputation was combined with osseous plugging of the medullary cavity and six of these cases had myoplasty as well The operations were performed with Nembutal anaesthesia and in sterile conditions Amputation was performed at the level between the proximal and intermediate third of the crus In the myoplastic cases a minor portion of the muscles was excised while in the cases



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without myoplasty the muscles were cut at the same level as the bone The medullary cavity was plugged by means of cortex obtained from the removed bone

The amputation stump healed without complications in 21 cases, while minor primary defects developed in two animals Most of the rabbits put weight on the stump, and a dry sore developed on the tip in three animals

The MBF was assessed by 133 Xenon (Lassen et al 1964) while the animals were under Nembutal anaesthesia Assessment of 133 Xenon clearance in resting muscle fails to provide a true picture of the MBF (Tønnesen 1969) For this reason muscle hyperaemia was produced by Histamine (Lindbjerg 1969) Isotonic solutions of 133 Xenon (Radiochemical Center, Amersham) and Histamine chloridum (1 mg per ml) were mixed at a ratio of three to one in a Mantoux syringe, and 0 02 to 0 07 ml was injected centrally by Mantoux needle into the quadriceps and triceps surae muscles on both sides

The rate of disappearance of the isotope was measured by a scintillation detector provided with NaJ crystal, screened off by a lead collimator and coupled to a ratemeter Immediately after establishment of the depot, the detector was adjusted above it, and the clearance curve was plotted by a logarithmic potentiometer recorder for 8 to 12 minutes

MBF was calculated according to Lassen et al (1964) on the basis of the logarithmic clearance curve

MBF $= -100 \times \lambda \times \ln(10) \times d\log C/dt = 161 \times D$ ml/100 g/minute where C denotes the concentration of isotope in tissue at a fixed time, λ is the isotope partition coefficient between tissue and blood $= 0.7$, and D denotes the fraction of a decade by which the tangent to the curve falls per minute

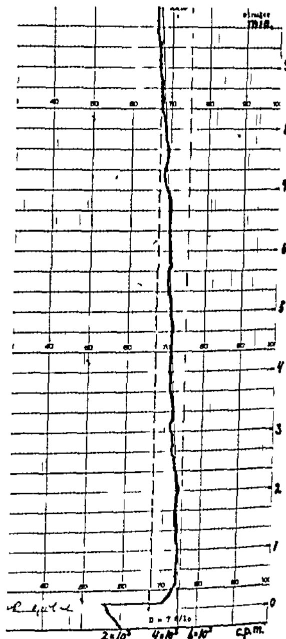


Figure 1 133 *Xe clearance curve, rabbit R 38 right quadriceps 3 days after amputation with myoplasty*
D = 7 8 10
MBF = 7 8/10 × 1 61 = 1 26 ml/100 g/min

RESULTS

MBF was determined prior to operations on 20 rabbits and the postoperative blood flow was expressed in per cent of the preoperative mean flow MBF in quadriceps and triceps surae, in the left and right leg respectively, was measured postoperatively on 121 occasions from periods of 1 hour up to 110 days after amputation

The clearance curve generally followed a rectilinear course throughout the period of registration (Figure 1) A phase of adjustment might occasionally occur during the initial few minutes before the fall set in In approximately one half of the measurements obtained at the stump a third phase was seen during which the concentration of the isotope was rapidly reduced to zero 6 to 8 minutes after in-

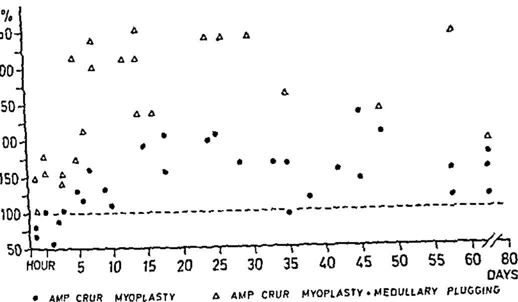


Figure 2 MBF in the amputation stump after amputation without myoplasty and after osseous medullary plugging from 1 hour to 80 days after operation

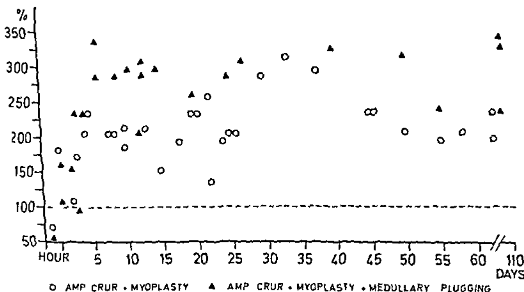


Figure 3 MBF in the amputation stump after amputation with myoplasty and after myoplasty combined with osseous medullary plugging from 1 hour to 110 days after operation

jection Out of a total of 464 single measurements, MBF could not be assessed in 52 cases because these curves did not follow an unambiguously rectilinear course

The postoperative MBF in the amputa-

tion stump is illustrated in Figures 2 and 3 Within the first days after *amputation without myoplasty* the flow was reduced About five days postoperatively, it was higher than the preoperative mean flow Between the second and fourth weeks it achieved a mean flow equal to 176 per cent of the preoperative flow, and after that time MBF in the stump was again reduced in six out of seven animals, while in one rabbit there was a further increase up to more than 200 per cent above the preoperative level

After *amputation with myoplasty*, MBF in the stump was initially reduced, but one day after surgery the flow was seen to rise, reaching a maximum about 30 days postoperatively Up to 80 days after amputation the mean flow was over 200 per cent of the preoperative flow

It appears from Figures 2 and 3 that *MBF in the amputation stump will increase* more rapidly and maintain a higher level for longer if the stump is closed by myoplasty When myoplasty was replaced by osseous plugging for stump closure, the MBF was studied to find whether the method of closure was responsible for the improved perfusion In Figure 2 it will be noted that the rise in MBF set in immediately after *amputation with medullary plugging* Within the first five days the mean flow was 152 per cent, and up to 75 days the flow rose to nearly 300 per cent of the preoperative value If medullary plugging and myoplasty were combined (Figure 3), the perfusion of the stump rises in the same was as after amputation with myoplasty, but the flow increases to a higher level thus equalling the increase observed after osseous plugging without myoplasty and it remains there *for up to four months* after surgery

There was an initial increase in MBF *in the ipsilateral quadriceps* after amputation with myoplasty (mean flow 151 per cent) which returned to normal after one week whilst the flow in the stump rose The same reaction was seen after amputation and medullary plugging After amputation without myoplasty, the flow in the quadriceps was unchanged until four weeks after operation when it was seen to rise to a mean flow of 133 per cent in the period 33 to 80 days postoperatively

The MBF in the *contralateral extremity* also changed after amputation The initial reduction in the flow in the crus stump was followed by a similar decrease in flow in the contralateral triceps surae When amputation did not include myoplasty, the flow in the contralateral quadriceps was also reduced during the first four weeks (mean flow 82 per cent), at which time the flow increased to a mean of 127 per cent in the period 33 to 80 days postoperatively After closure by myoplasty, an initial increase in the flow *in the contralateral quadriceps* was observed, during the first week the mean flow was 139 per cent of the preoperative flow The same reaction was seen after medullary plugging and myoplasty, while medullary plugging without myoplasty was followed by a more pronounced rise *in MBF both in the quadriceps* and triceps surae It seems that the MBF in the contralateral quadriceps changes to equal the flow in the quadriceps on the side exposed to operation

DISCUSSION

This study demonstrates that it is possible to assess MBF in rabbits by means of 133 Xenon and Histamine Correlation between flow rates is fair, and the unambiguous changes in MBF after amputation make is possible to evaluate the influence of *amputation on* MBF

Preliminary studies of MBF in rabbits by means of 133 Xenon without Histamine failed to demonstrate any clear cut changes after amputation *The clearance* curves were characterized by a distinct initial fall followed by a flattening

of the curve Tonnesen (1969) obtained a similar course for the resting flow in isolated gastrocnemius muscle from cats, and observed that after stimulation of the sciatic nerve the course was rectilinear and the clearance equalled the blood flow when measured directly Lindbjerg (1969) suggested that the fluctuating flow in the resting muscle might be due to the fact that the isotope exchange between blood and tissues varies because of a heterogeneous distribution of open capillaries in resting muscle Stimulation of nerves will result in a four fold increase in the number of capillaries, and the same effect is obtained with Histamine After Histamine stimulation, the muscle appears as a homogeneous tissue and the clearance curve runs a rectilinear course Lindbjerg considered that blood flow might be influenced by different doses of Histamine and found that MBF reached a maximum after 4 to 100 μg Histamine In this study, the dose of Histamine in the depot varied between 10 to 20 μg, and within the limits of 3 to 40 μg there was no difference in the Histamine effect According to Lindbjerg, the size of the isotope depot might also influence the flow Depots used in the present study were 0 03 to 0 08 ml and within the 0 02 to 0 12 ml range the size of depots had apparently no influence on the MBF

It has been demonstrated in this study that MBF in the amputation stump is reduced immediately after amputation This is in agreement with the findings of Erikson & Olerud (1966) who, using arteriography on live rabbits after amputation of the crus with myoplasty, observed an initial constriction of arteries and veins which may be explained by an involuntarily provoked spasm Two to three days later they observed a dilation which reached a maximum four weeks later and occasionally persisted for more than four months In the present study, the MBF in the stump was seen to run a similar course after amputation with myoplasty, while after amputation without myoplasty the rise in flow did not set in until one week postoperatively, decreasing again after the fourth week This difference was not observed by arteriography on young rabbits (Hansen-Leth & Reimann 1972) which showed hypervascularization of the amputation stump one to three weeks after amputation of the crus, irrespective of whether myoplasty had been used

There are two aims when using myoplasty, first to reorganize the continuity of muscles, and secondly to close the medullary cavity with a view to normalizing the intraosseous pressure and venous reflux from the stump (Dederich 1963) In order to investigate this second problem MBF was assessed after osseous plugging of the cavity The flow was found to be greater than after myoplasty and the increase was seen to set in immediately after the operation in contrast to the findings observed when the medullary cavity was left open after amputation In clinical investigations with arteriography, Langhagel (1968) observed that osteomyoplasty intensified the vascularization in the stump for a period of one year, at which time vascularization equalled the state after spontaneous closure of the medullary cavity Bone healing of the stump is analogous with healing of a fracture (Hulth & Olerud 1962), and it has previously been shown (Hansson 1967) that plugging of the medullary cavity serves to stimulate the growth of bone These facts may be contributory causes to the intensified MBF in the stump after osseous medullary plugging

It has been demonstrated in this study that amputation of the crus has a contralateral effect in the form of a change in MBF in the contralateral quadriceps, equalling MBF in the quadriceps on the side exposed to surgery A contralateral effect has previously been described by

tion stump is illustrated in Figures 2 and 3 Within the first days after *amputation without myoplasty* the flow was reduced About five days postoperatively, it was higher than the preoperative mean flow Between the second and fourth weeks it achieved a mean flow equal to 176 per cent of the preoperative flow, and after that time MBF in the stump was again reduced in six out of seven animals, while in one rabbit there was a further increase up to more than 200 per cent above the preoperative level

After *amputation with myoplasty*, MBF in the stump was initially reduced, but one day after surgery the flow was seen to rise, reaching a maximum about 30 days postoperatively Up to 80 days after amputation the mean flow was over 200 per cent of the preoperative flow

It appears from Figures 2 and 3 that MBF in the amputation stump will increase more rapidly and maintain a higher level for longer if the stump is closed by myoplasty When myoplasty was replaced by osseous plugging for stump closure, the MBF was studied to find whether the method of closure was responsible for the improved perfusion In Figure 2 it will be noted that the rise in MBF set in immediately after *amputation with medullary plugging* Within the first five days the mean flow was 152 per cent, and up to 75 days the flow rose to nearly 300 per cent of the preoperative value If medullary plugging and myoplasty were combined (Figure 3), the perfusion of the stump rises in the same was as after amputation with myoplasty, but the flow increases to a higher level thus equalling the increase observed after osseous plugging without myoplasty and it remains there for up to four months after surgery

There was an initial increase in MBF in the *ipsilateral quadriceps* after amputation with myoplasty (mean flow 151 per cent) which returned to normal after one week whilst the flow in the stump rose The same reaction was seen after amputation and medullary plugging After amputation without myoplasty, the flow in the quadriceps was unchanged until four weeks after operation when it was seen to rise to a mean flow of 133 per cent in the period 33 to 80 days postoperatively

The MBF in the *contralateral extremity* also changed after amputation The initial reduction in the flow in the crus stump was followed by a similar decrease in flow in the contralateral triceps surae When amputation did not include myoplasty, the flow in the contralateral quadriceps was also reduced during the first four weeks (mean flow 82 per cent), at which time the flow increased to a mean of 127 per cent in the period 33 to 80 days postoperatively After closure by myoplasty, an initial increase in the flow in the contralateral quadriceps was observed, during the first week the mean flow was 139 per cent of the preoperative flow The same reaction was seen after medullary plugging and myoplasty, while medullary plugging without myoplasty was followed by a more pronounced rise in MBF both in the quadriceps and triceps surae It seems that the MBF in the contralateral quadriceps changes to equal the flow in the quadriceps on the side exposed to operation

DISCUSSION

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It has been demonstrated in this study that amputation of the crus has a contralateral effect in the form of a change in MBF in the contralateral quadriceps, equalling MBF in the quadriceps on the side exposed to surgery A contralateral effect has previously been described by

Jaya (1958) who observed that ligature of the femoral artery in rats and rabbits resulted in strictures at the same level in the contralateral femoral artery. Barnes & Trueta (1942) described an analogous effect which might occur if a tourniquet was applied. Liu (1968) and Lewis & Lim (1970) assessed the blood flow after a blunt trauma and observed that the flow was reduced in the contralateral extremity, while Rhinelander (1968), by means of micro-angiography, demonstrated a dilation of the cortical blood vessels in the contralateral limb after fractures in dogs.

These assessments of MBF have disclosed that the postoperative increase in the flow in the amputation stump is most pronounced when amputation is combined with osseous plugging of the medullary cavity. From a clinical point of view this observation may be of interest but further research is necessary to show whether medullary plugging brings about a similar increase in MBF in man.

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Acta orthop scand 47 619 628 1976

ATLANTO AXIAL FUSION IN RHEUMATOID ARTHRITIS

A New Method of Fixation with Wire and Bone Cement

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Twenty eight occipito-cervical fusions performed over the past 4 years in patients with rheumatoid arthritis are discussed All of the patients with one exception had signs of neurological involvement preoperatively due to pressure on occipital nerve roots spinal cord and/or vertebral arteries A surgical technique using wire pin and bone cement and permitting early mobilization without external fixation was used and is described in detail The clinical results were excellent in 21 cases with an additional five patients showing improvement One patient did not benefit from surgery and one had no symptoms preoperatively The results are encouraging and the possibility of early mobilization (the day after surgery) is of the utmost importance for this group of patients

Key words atlanto axial luxation rheumatoid arthritis bone cement fusion

Accepted 19 viii 76

Spontaneous luxation of the atlanto-axial joint is a well recognized and common complication of rheumatoid arthritis (RA) It is supposed to occur either as a result of loosening of the attachments of the transverse ligament of the atlas or when the odontoid process shortened by erosion allows the intact ligament to slip over the tip of the process The mechanical properties of the joints in this region the prerequisites for dislocation and the morbid anatomy of atlanto axial luxation in RA have been discussed by Werne (1957) and by Ball & Sharp (1971) Cervical luxations of other levels are also quite common in RA (*Lidgren* et al 1974) but will not be dealt with in this paper

The diagnosis of atlanto-axial luxation is based on roentgen examinations The radiograms must be taken during maximal flexion and maximal extension to investigate the extent of mobility in the joints The recorded incidence of luxation varies with the selection of patients, the diagnostic criteria and the radiographic technique Thus Conlon et al (1966) and Mathews (1974) demonstrated luxation roentgenologically in 25 per cent of cases with RA, and this rate is corroborated by our experience A higher incidence, 37 per cent, was reported by Meikle & Wilkinson (1971)

This investigation was financially supported by Alfred Österlunds Stiftelse and by Riksforbundet mot Reumatism

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Figure 1 Lateral radiograms of case 26 in maximal extension (A) and flexion (B) The distance between the anterior arch of the atlas and the odontoid process increases from 4 21 mm

with somewhat wider diagnostic criteria Martel (1961) found an incidence of 73 per cent in a group of patients complaining of occipital pain

Three different varieties of atlanto-axial luxation may be found in RA forward, downward, or backward luxation of the atlas in relation to the axis Most common is "forward luxation" where skull and atlas move horizontally above the axis A forward luxation is said to exist if the distance between the odontoid process and the corresponding articular surface of the atlas exceeds 3 mm on the



Figure 2 Lateral tomogram of a case with mostly downward luxation with the tip of the odontoid process protruding into the foramen magnum (This case was not operated on)

radiogram during anterior flexion of the head (Figure 1 A and B) Forward luxation is usually unstable and is mostly rapidly and substantially reduced by skull traction

Less common is downward luxation where the anterior arch of the atlas is tilted downwards in front of the axis The odontoid process then protrudes through the arch of the atlas and the tip of the process usually reaches more than 5 mm above McGregor's (1948) baseline (a line drawn from the upper surface of the posterior edge of the hard palate to the most caudal point of the occipital bone) A preserved odontoid process may then protrude intracranially through the foramen magnum (Brattstrom et al 1973) (Figure 2) The posterior arch of the atlas frequently makes a deep indentation in the spinal canal immediately below the foramen magnum The vertebrae are much less mobile in downward luxation than in forward luxation during flexion extension of the neck Reduction during skull traction is insignificant or nonexistent even if the traction is applied for extended periods of time

Isdale & Corrigan (1970) have described backward luxation in RA but this seems more unusual and such cases are not included in our experience

Symptomatology

Most patients with atlanto axial dislocation in RA have no symptoms However Smith et al (1972) found that 30 patients in a series of 130 cases with roentgenologically verified luxation had or developed some symptoms during their period of observation Rana et al 1973 found symptoms from the luxation in 37 out of 41 cases In another series (Stevens et al 1971) cervical myelopathy was found in two thirds of the cases with atlanto axial luxation Mathews (1974) stated that 5 years after diagnosis one third of the patients with forward luxation and half of those with downward luxation had developed long tract symptoms

The earliest symptoms frequently seem to be caused by a compression of the occipital nerve roots resulting in radiating pain in the occipital region an occipital rhizopathy This may precede other symptoms by several years If the luxation is unstable the patient may experience crepitations or an unpleasant feeling that the head is slipping backwards or forwards

Increasing luxation may cause a gradually increasing compression of the spinal cord resulting in myelopathy and long tract symptoms This is frequently initially observed by the patient as numbness and weakness in fingers hands and arms and may rapidly progress to pronounced tetraparesis Severe dislocation may also cause compression of vertebral arteries with signs of brainstem ischemia such as vertigo or cranial nerve involvement Spinal cord or vertebral artery compression might ultimately result in respiratory arrest and death (Cohen 1969 Mikulowski et al 1975 Webb et al 1968) At present a clear distinction in clinical symptoms between cases with forward or cases with downward luxation of the atlas has not been made

Therapy

As most patients have no symptoms or only slight symptoms from their atlanto axial luxation no therapy is usually required External support may sometimes reduce or eliminate moderate symptoms However in some cases reposition and surgical stabilization may be indicated In our series patients were considered eligible for surgery when an atlanto-axial luxation had been verified roentgenologically and when the occipital rhizopathy was unaffected by neck collar treatment or if collar treatment was not tolerated Surgery was always chosen if there were

Table 1 Basic data of 28 patients with atlanto axial luxation treated by occipito cervical fusion

Female	23
Male	5
Mean age at operation	59 (27–73) years
Mean duration of disease	17 (5–40) years
Mean duration of occipital rhizopathy	26 (6–80) months
Seropositive	23
Steroid treatment > 1 year	18

signs of spinal cord and/or vertebral artery compression Only in one patient was instability alone an indication for surgery In this case movements in the affected joints were excessive during extension-flexion and amounted to 17 mm (case 26 in Table 2)

Choice of surgical procedure

Fusion of the occiput to the upper cervical spine must be the treatment of choice, as it tends to normalize the dislocation anatomically Various techniques employing bone grafts have been used also in RA (see Discussion) Prolonged immobilization during bed rest or in traction seems, however, to be a prerequisite for fusion Extended periods of time in bed are particularly harmful for the RA patient, which is a good reason for using

Table 2 Preoperative symptoms and results of surgery in 28 cases

Case	Sex	Age (years)	Distance atlas odontoid proc (mm) extension	flexion	Downward luxation (see text)	Symptoms All but one severe neck p
1	F	47	8	12		Crepitations Loose head
2	F	55	10	15		Hemiparesis
3	F	61	2	12	+	Tetraparesis
4	F	63	2	10		Radiating brachial pain
5	M	61	10	10		Tetraparesis
6	F	64	8	14		Tetraplegic Bedridden
7	M	54	11	15		Tetraparesis Vth nerve symptoms
8	M	49	3	10		Tetraparesis
9	F	54	10	10		Tetraparesis
10	F	54	14	20		Tetraparesis
11	F	66	3	6	+	Tetraplegic Bedridden
12	F	68	5	5	+	Severe pain only
13	F	62	4	11		Tetraparesis
14	F	67	10	10	+	Dizziness Bedridden
15	F	64	5	5	+	Tetraparesis Bedridden
16	F	68	0	16		Severe pain only
17	F	48	3	15	+	Tetraparesis Vth nerve symptoms
18	M	67	3	15		Severe pain only
19	F	63	5	7		Tetraparesis
20	F	59	2	6		Hemiparesis
21	F	69	10	10		Tetraparesis
22	F	66	8	9	+	Radiating brachial pain
23	F	73	7	15	+	Severe pain only
24	F	68	2	13		Hemiparesis Bedridden
25	F	27	10	10		Crepitations Psoriasis
26	M	35	4	21		Severe symptom free luxation and instability
27	F	67	8	12		Tetraparesis Vth nerve symptoms
28	F	37	6	9		Radiating brachial pain

…sion
…sion [1]

(± 1 mm)

a technique allowing early mobilization

This paper reports the experience gained from 28 patients with atlanto-axial luxation, treated with a modification of a surgical procedure initially designed for metastatic disease of the spine. Surgery has been performed as a joint orthopaedic and neurosurgical procedure.

PATIENTS

During the 4 years 1971–1974 28 patients with atlanto axial luxation have been treated surgically. The first ten cases were included in a preliminary report (Brattström & Granholm 1973). Patients operated on form a small fraction of a larger number of cases with RA of the cervical spine seen during these years. Twenty-seven of the patients were suffering from severe classical RA whereas one had psoriatic polyarthritis. Some basic data about operated cases are summarized in Table 1.

Preoperative roentgenological and clinical data from the 28 patients operated on are found in Table 2. Instability could be demonstrated roentgenologically in 17 patients, i.e., the distance between the odontoid process and the corresponding articular surface of the atlas changed more than 3 mm between films taken in maximal flexion and in maximal extension of the neck. All patients but one had a severe occipital rhizopathy. Twenty one patients had signs of spinal cord and/or vertebral artery compression. Several patients experienced a grinding noise in the neck when their heads slid backwards and forwards during neck movements.

matoid arthritis with cervical luxation treated by occipito cervical fusion

Observation time (years)	Result	Complications and remarks
4	Good	
3 9/12	Good	
3	Good	
2	Good	Break of wire 1 year postoperatively Symptom free
2	Good	Wound infection see text
2	Good	Much improved Wheelchair bound
1 9/12	Fair	Wound infection Cement and wire removed
1 9/12	Good	
1 9/12	Good	
2	Good	
2	Good	Three stage operation Wheelchair bound See text
1 6/12	Good	Laminectomy of C 1
1 6/12	Unimproved	Technically unsuccessful Reoperation after 2 weeks.
1 6/12	Good	Laminectomy of C 1
4 12	Fair	Laminectomy of C 1 Wheelchair bound. See text
1 6/12	Good	
1 6/12	Good	
4/12	Fair	Fracture of C 2 Reoperation See text
9/12	Good	Fracture of C 2 Reoperation
6/12	Good	
6/12	Fair	
3/12	Good	
2/12	Fair	Laminectomy of C 1
2/12	Good	
2/12	Good	Psoriatic arthritis
2/12	—	Break of wire 1 month postoperatively See text
2/12	Good	
1/12	Good	

Fair less pain preoperative neurological deficit partly reduced

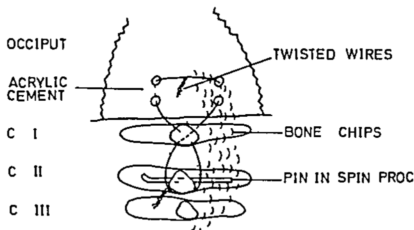


Figure 3 A

Figure 3 Schematic drawing showing the surgical technique with the application of wire pin acrylic cement and bone chips A posterior view B lateral view C cranial view of C 2 See text The skull and C 1 are pulled dorsally (see arrow in Figure 3 B) when the wire is twisted

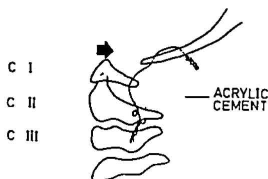


Figure 3 B

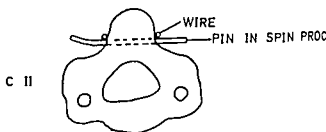


Figure 3 C

SURGICAL PROCEDURE

Initial experience of the technique prompted a preliminary report on the ten first cases (Brattstrom & Granholm 1973) Increasing acquaintance with the condition has led to a routine being followed for the treatment of the last 15 cases

Skull traction

Skull traction is always used It is started before surgery and is maintained during the procedure Crutchfield tongs are used and the patient is placed on a Stryker frame If the radiograms indicate that the luxation is unstable (mainly forward luxation) traction is applied the day before surgery If the luxation is stable (mainly downward luxation) the patient is kept in traction for a few days before surgery Any possible reduction of the luxation occurs rapidly, so there seems to be no reason to prolong the period of traction for more than a week before the patient is operated on If the ... in acute neurological distress

nosis always is skull traction

Anesthesia

General anesthesia is used and is administered through an endotracheal tube The tube is introduced with the patient in supine position on the Stryker frame during skull traction The traction prevents hazardous bending or movements of the neck when the tube is in place when the patient is turned to the prone position and during surgery

Occipito cervical fusion

From the morning surgery is scheduled the patient receives Cloxacillin for 10 days 1 g four times a day Following intubation the patient is placed in a prone position on the Stryker frame With the guidance of previously taken radiograms the head is moved and tilted in such a position that the atlanto axial dislocation is reduced as far as possible One operative field is prepared and draped in the occipito cervical area and another over the posterior iliac crest from where bone chips are taken A straight mid line incision is made from the external occipital protuberance down to the spinal process of C 4 Muscles and periosteum are removed from the occiput and from the



Figure 4 Postoperative radiogram of Case 28

spinal processes and arches of C 1 and C 2 (occasionally also from those of C 3) The procedure is schematically described in Figures 3 A B and C Four burr holes are placed in the occipital bone and a neurosurgical trephine is suitable for this part of the procedure Two of the burr holes should be placed as close as possible to the edge of the foramen magnum The posterior arch of the atlas is dissected free and a nylon ligature is passed between the arch and the dura A loop of a stainless steel wire is pulled around the arch of the atlas by means of the nylon ligature The loop is cut and the two free wires are crossed under the arch One cranial end of a wire is bent and passed in and out through the left sided burr holes and the other is bent in the same way through the holes on the right side The wire ends are then twisted in the mid line below the occipital protuberance If the arch of the atlas is very thin and osteoporotic the wires are left un crossed to spread the mechanical stress over a larger area

A pin originally designed to fix a fractured medial malleolus is passed through the spinal process of C 2 its way through the process being prepared by a clip of a heavy towel clamp The end of the pin that will later be encased in bone cement is bent slightly to provide a better anchorage to the cement The function of the pin is twofold to hold the bone cement in place and to prevent the wire from slipping

One caudal wire end is now passed dorsally to the pin and twisted with the other wire end passed in the same way on the other side of the spinal processes If the spinal process of C 2 is small or very osteoporotic, the wires may be twisted below the spinal process of C 3 with or without a pin through that spinal process Maximal reduction of the luxation occurs when the wires are twisted A little more than one half of the exposed bone surface is now covered with bone cement (Orthopaedic Bone Cement Type 1 CMW Laboratories Ltd Blackpool England), including two occipital burr holes the two wire twistings the spinal processes and the bent end of the pin The production of heat in the plastic encasement is counteracted by rinsing with physiologic saline solution Uncovered bone surface of occiput and laminae is partly decorticated with a dental drill or a chisel and covered with bone chips from the iliac crest The wounds are closed in separate layers The patient is then turned to the supine position whereupon the skull traction tongs and the endotracheal tube are removed He is returned to the ward in an ordinary patient s bed and is allowed out of bed on the following day in a soft neck collar which he is supposed to use for 4 weeks (Figure 4)

Downward luxation may need special consideration during surgery If the luxation is pronounced the posterior arch of the atlas makes a deep indentation into the dural sac immediately below the foramen magnum If it is impossible to reduce the luxation it may then be necessary to perform a laminectomy on the posterior arch of the atlas in order to obtain



Figure 5 Postoperative radiogram of Case 15 Downward luxation Laminectomy of C 1 The wire goes from the occiput directly to C 2 and C 3

decompression of the spinal cord The wires are then passed from the caudal occipital burr holes straight down to the pin through C 2 and/or C 3 (Figure 5)

RESULTS AND COMPLICATIONS

All patients but one experienced an amelioration of preoperative symptoms and the pain relief was almost complete in 21 cases Five still have some radiating pain or weakness but describe themselves as improved compared with their preoperative state Only one patient is completely dissatisfied with the treatment Particularly gratifying was the neurological improvement in several cases with severe preoperative paresis The results of surgery are summarized in Table 2

No deaths occurred at surgery or during the immediate postoperative course Four patients have died during the follow-up period Case 5 died 2 years after surgery with bronchiogenic carcinoma Case 11 was operated on in three stages 1) transoral removal of odontoid process protruding intracranially through the foramen magnum, 2) after 3 weeks occipito-cervical fusion, 3) after another 2 months anterior fusion at the C 7–D 1 level She improved and could manage a wheelchair but died 2 years after surgery with chronic urinary tract infection Case 15 died 4 months after surgery from a pulmonary embolus Case 18 died suddenly 4 months after surgery from a myocardial infarction with ventricular rupture

Two cases acquired wound infections both handled before routine preoperative treatment with antibiotics was instituted One case was symptom-free from luxation and infection under continuous treatment with Cloxacillin until he died 2 years later from a bronchiogenic carcinoma (Case 5) The fusion material was removed after 1 year in the other patient (Case 7)

The spinal process of C 2 broke a few weeks after surgery in two patients Both were re-operated and re-fused using a more caudal spinal process or laminae for anchoring the caudal part of the wire (Cases 18 and 19) The wire broke in two cases In one of these the degree of luxation did not increase, and she has not been re-operated on (Case 4) Surgery is planned for the other case, in whom reluxation has occurred (Case 26)

DISCUSSION

The indications for different types of fusion of the atlas in various diseases have been discussed by Hamblen (1967) Simple instability between the first and second cervical vertebra, such as may occur with fractures of the dens, does not require fusion of the occiput to the upper vertebral spine provided the posterior arch of the atlas is intact It is then sufficient to fuse the atlas to the vertebral arches below Fusion of the atlas to the axis and bone cement encasing was used by Alsharif (1969) in two children with atlanto-axial luxation due to RA RA at the atlanto-axial level is, however, frequently a more widespread disease engaging several joints and the adjacent bone This necessitates a more extensive procedure, mainly because of the fact that the arch of the atlas usually is thin and osteoporotic ("a little larger than the wishbone of a chicken") (Newman & Sweetnam 1969)

Fusion of the occiput to the upper cervical spine must then be the treatment of choice This was earlier employed in traumatic injuries by Foerster (1927), who used a fibular graft to stabilize the neck in a case of fracture of the dens The advantage of iliac bone grafts in the procedure was first recognized by Kahn & Yglesias (1935) There is a large number of reports in the literature from recent years on traumatic injuries treated by occipito-cervical fusion with iliac bone grafts, and also in RA (Crellin et al 1970, Ferlic et al 1975 Hamblen 1967, Hauge

1958 Meijers et al 1974) Prolonged im mobilization during bed rest seems how ever to be a prerequisite for fusion However extended periods of time in bed are particularly harmful for the patient with RA which has been our reason to look for a technique allowing early mobiliza tion

A suitable technique was initially de scribed for metastatic disease of the spine by Scoville et al (1967) and con sists in wiring of laminae to occiput and acrylic plastic encasement of wires oc ciput and spinous processes The tech nique employed in the present series of patients is slightly altered The wires are used also to accomplish maximal reduc tion of the luxation It was also felt that it was important to use bone chips to promote bone healing

One observation from the present series of cases was the difficulty experienced in making an adequate neurological assess ment of the patient Sensory examina tion is frequently difficult as numerous surgical procedures to joints leave areas around the scar with reduced ability to perceive touch or pin prick Muscular weakness is caused by medullary or nerve root compression but is also com mon in the severely ill RA patient and due to inactivity or stiffness Reflex activity finally may be reduced or ab sent around severely diseased joints It was however usually possible to sep arate different qualities of pain from each other Radiating pain originating from nerve root compression was de scribed as a "new sensation In con clusion it is necessary to depend more on the history than on the doubtful value of one neurological examination

Before this technique was initially em ployed it was feared that the patients might be incapacitated by their reduced range of movement in the cervical spine None has complained of this however and it seems as if the reduced range of movement in the fused area has been compensated for by increased movement at lower levels

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a orthop scand 47, 629 631 1976

AN UNUSUAL CASE OF SUBLUXATION OF C.3–C.4

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A case is reported of spontaneous subluxation of C 3 on C 4 in a 6-year old boy due to an upper respiratory infection after surgical treatment for muscular torticollis

Key words cervical subluxation, cervical infection, torticollis

Accepted 25 ix 76

Simultaneous subluxation of the upper three vertebrae due to upper respiratory infection combined with minor trauma has been reported before by Wilson et al (1940), Hunter (1968) and others To the best of our knowledge, subluxation at the level below C 3 due to the above mentioned reason, particularly during the period of treatment for muscular torticollis, has never been recorded

CASE REPORT

W a 6 year old boy who was born after a normal pregnancy by a vertex delivery using forceps on the head was observed to have a sterno mastoid tumour on the left side a few days after birth Nobody noticed any abnormality until he was 5½ years old when his parents suddenly became aware of his tendency to hold his head tilted to the left side On examination he appeared a fit young boy However examination of his neck revealed a torticollis due to a very tight clavicular head of the left sterno mastoid muscle It was also noted that there

and formal release of the sternal and clavicular heads of the sterno mastoid was carried out Postoperatively he was immobilized in a Minerva type plaster of Paris in the over corrected position for a period of six weeks followed by four weeks gentle physiotherapy While he was in the plaster there were two occasions when he had upper respiratory infections complicated by right otitis media which were treated with antibiotics by h's doctor He had had similar



Figure 1 Lateral X ray of cervical spine prior to surgery



Figure 2 Lateral X ray of cervical spine 12 weeks after surgery and 6 weeks after removal of the Minerva plaster cast



Figure 3 The subluxation reduced and held in a collar

infections on a number of occasions in the past Six weeks after removal of the Minerva plaster he presented in the Outpatient Department complaining of pain in his neck and with his head held in flexion X ray pictures of the cervical spine showed an anterior subluxation of C3 on C4 (Figure 2) He was readmitted to the Nuffield Orthopaedic Centre his subluxation was easily reduced with cervical traction (Figure 3) and was thereafter held for six weeks in a plaster collar

DISCUSSION

Sore throat and upper respiratory infection combined with some sort of injury sometimes even a minor one can cause subluxation of the cervical spine in children A Wittek (1908) was the first to mention this disorder in reporting a case of spontaneous atlanto axial subluxation and he suggested that a metastatic effusion into the joint distended the ligaments of the atlanto axial joint His explanation was accepted later by L J Berkheiser & F Seidler (1931) M J Wilson et al (1940) and A W Sullivan (1949) Many others have reported cases of subluxation of C1 on C2 or C2 on C3 or combinations of these (B Eriksson (1960) G A Hunter (1968) and A B Ferguson (1975)) The inherently unstable nature of the atlanto axial joint and the nearly horizontal attitude of the upper cervical facet joints has been used to explain the localization of the disorder to these levels In our case the C3 C4 level was involved and it is also unique in occurring after surgical treatment for muscular torticollis

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Acta orthop scand 47, 632–634, 1976

FRACTURE OF THE FIRST RIB

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Fifteen cases of isolated fracture of the first rib are submitted The mechanism of the fracture is discussed It proved compatible with the descriptions in the literature caused either by direct trauma to the shoulder, a sudden violent contraction of juxtacostal muscles, or else it was a chance finding, without any history of trauma and as such interpreted as a fatigue fracture A case of Horner's syndrome complicating a fracture of the first rib is also described

Key words complications, first rib, fracture, mechanism of fracture

Accepted 14 ix 76

The first rib lies deep in the cervical root protected by the muscles and bones of the shoulder girdle Therefore, an isolated fracture of this rib is rare A total of about 270 cases are on record, 28 of them bilateral Isolated fracture of the first rib often occurs without a history of trauma (Alderson 1947), or after a trauma which is rarely linked to the fracture Therefore, the mechanism of this fracture has been discussed by many authors in the past (Jones 1869, Aitken & Lincoln 1939, Proctor et al 1945, Brook 1959, Joshi et al 1965, Frangakis 1967, Blichert-Toft & Nielsen 1968, Guillermand 1971) Some authors have even doubted the existence of such a fracture, interpreting the finding instead as a developmental anomaly (Bowie & Jacobson 1945)

The object of submitting the present series of 15 consecutive cases of first-rib fractures is partly to elucidate the fracture mechanism and partly to emphasize two cases which gave rise to erroneous diagnostic reflections

PATIENTS AND METHODS

Fifteen patients, all males aged 9–63 were treated in the Frederiksberg Hospital Copenhagen, from 1966 to 1970 In 14 cases the fracture was unilateral and the fifteenth was bilateral By nature of trauma the 15 patients may be divided into three groups

Group 1 Fracture arising after direct trauma to the shoulder girdle

Four patients sustained direct trauma to the shoulder in traffic accidents In two of them the fracture was unilateral, the third patient had a bilateral fracture after the steering column of his car had pressed against the manubrium sterni and the fourth case will be described in some detail

A 9 year-old boy was admitted to hospital after being knocked over by a lorry *He sus*tained a left-sided fracture of the first rib bilateral clavicular fracture, pneumothorax and cranial contusion The patient was unconscious and as his left pupil was inactive to light and contracted there was a suspicion of brain stem contusion and/or hypoxic brain damage When the acute phase was over, it was found that a left sided Horner's syndrome had developed (miosis ptosis and enophthalmos) due to *in*jury of the inferior cervical ganglion elicited by fracture of the first rib

Group 2 Fracture arising after indirect trauma to the shoulder girdle

There were three patients in this group Two sustained fractures on heavy lifting and the third while playing tennis The symptoms were sudden severe pain anteriorly on the neck at the site of the scalenic muscles

Group 3 Fracture occurring without a history of trauma

While the seven patients in groups 1 and 2 showed symptoms leading to treatment in the emergency ward or an in patient department fractures in eight patients were found accidentally in routine chest radiography While none of the patients had symptoms or histories of trauma all eight were exposed to daily physical stress on their shoulder girdle in their occupation One of the case histories will be given below

A 21 year old man was admitted to hospital in a poor general condition with low grade fever which he had had for about a month. Four years previously he had undergone an operation for a tumour of the right parotid gland The histological diagnosis had been a benign mixed parotid tumour Chest radiography revealed a swelling on the middle of the first rib on the right (Figure 1) It was interpreted as a metastasis To confirm the diagnosis a biopsy was taken but it merely showed ordinary callus without gross or microscopic signs of malignancy Subsequent tomography confirmed that this was a fracture of the first rib with callus formation The patient who never before had any symptoms from the shoulder was alive and well five years later



Figure 1

DISCUSSION

As early as 1869 it was pointed out by Jones that traumatic fracture of the first rib was extremely rare Owing to the deep situation of the first rib in the cervical root most cases of traumatic fractures are associated with fractures of the clavicle (Breslin 1937, Knoep 1941 Iqbal 1971) Of the four cases in our series however only one co existed with clavicular fracture Incidentally this was the only patient who developed complications in the form of pneumothorax and more interestingly Horner s syndrome We have not been able to find any report of such a complication in the literature but it has been mentioned as a theoretical possibility

The three patients in group 2 presumably sustained their fractures as a result of sudden violent contraction of the scalenus anterior muscle (two by heavy lifting and one by playing tennis) According to several authors (Aitken & Lincoln 1939, Brook 1959, Frangakis 1967), the mechanism of this form of fracture is a sudden strong contraction of the scalenus anterior muscle combined with traction on the arm The scalenus anterior and the upper slip of the anterior serratus insert and exert opposite traction on each side of the subclavian sulcus—leading to fracture of the weak point on a level with the sulcus (Figure 2) A similar mechanism is said to be elicited by a sudden unexpected hyperextension of the cervical spine (Joshi et al 1965, Frangakis 1967) All three patients in this group had fractures at the site of the subclavian sulcus

The most published cases of isolated

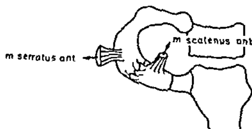


Figure 2

fractures of the first rib, like ours, have occurred without a history of trauma and have been silent Most authors have interpreted this type of fracture as fatigue fracture (Alderson 1947, Jenkins 1952, Freiberger & Mayer 1964, Jamil & Nath 1970, Dietzel & Schirmer 1972) However, the most convincing description is that by Proctor et al (1945) who found this fracture in infantry soldiers carrying heavy barracks bags—"barracks-bag" fracture

The absence of symptoms made Bowie & Jacobson (1945) doubt that a fracture was present and they suggested it was a congenital developmental anomaly This was later rejected by Alderson (1947), Freiberger & Mayer (1964), and by Blichert-Toft & Nielsen's (1968) independent follow-up study of stress fractures which revealed spontaneous bony union and which could not be taken to mean that this was a developmental anomaly

In one of our cases a pathological fracture of the first rib was suspected, but this suspicion was disproved In the literature we have been unable to find any accounts of pathological fractures of the first rib Guillermand (1971) reported three cases of tuberculous metastases, but this diagnosis was not confirmed by biopsy, and Guillermand himself suggests the possibility of a fatigue fracture

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Acta orthop scand 47, 635–642 1976

PELVIC STRENGTH AFTER MAJOR AMPUTATION OF THE SACRUM

An Experimental Study

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Major sacral resections up to the level of S 1 and even higher have been performed This has raised the question of the degree to which such operations weaken the pelvic ring Fifteen cadaver pelves, including the fifth lumbar vertebra, were loaded to failure, five unresected, five after resection of the sacrum between S 1 and S 2 and five after resection about 1 cm below the promontory The weakening of the pelvic ring amounted to approximately 30 per cent with the former type of resection and 50 per cent with the latter Taking into consideration the calculated normal load on L 5 in upright standing it seems safe from this study to allow patients to stand with full weight bearing at an early stage postoperatively after submaximal resection of the sacrum

Key words pelvis sacrum, stability, amputation

Accepted 10 viii 76

Tumors in the sacrum are often discovered at a relatively late stage and may reach a considerable size before coming under surgical treatment The possibilities for radical removal of large sacral tumors, without doing a hemicorporectomy, are limited by the necessity to preserve, or reconstruct, a strong connection between the lumbar spine and the pelvic skeleton The uppermost part of the sacrum with the corresponding parts of the sacroiliac joints should, if at all possible, be preserved To our knowledge no investigations have been published that give information about how large a part of the sacrum can be removed without jeopardizing the strength of the pelvic ring However, MacCarty et al (1952) and Localio et al (1967) have reported sacral resections up to the S1 level with uneventful recoveries Hays (1953) even performed a resection through the first sacral segment, leaving half of it as a bridge between the iliac bones, and the patient managed with a short leg brace Evans & Lissner (1959) have carried out static vertical load tests on eleven specimens consisting of intact lumbar spine and pelvis and found the maximal load to be 290–1350 pounds (1290–6008 N, mean value 3514 N) Their material included both embalmed and unembalmed specimens The localization of the injury at specimen failure was not given

During recent years five patients with large sacral tumors have been operated



a



b

Figure 1 Lateral radiograms of the L5–S1 region of a middle aged male patient 9 weeks (a) and 2 years (b) after resection of the sacrum through the lower part of the S1 vertebra Note the skeletal adjustment cortical appearance (arrow in b) of the osteotomized initially cancellous (arrow in a) surface of the S1 vertebra

upon in our department The whole of the sacrum was removed except for the first sacral segment to a varying extent Adjacent iliac bone was removed on both sides so that the patients lost a large part of the sacroiliac joints and their ligaments All these patients recovered well from the operation and it was possible to mobilize them to walking initially with the aid of a stroller or crutches These observations led to the present study The purpose was to try to clarify to what degree the pelvis is weakened by a major sacral resection including various parts of the sacroiliac connections and to evaluate the retained strength in relation to the estimated normal load This information should be helpful in determining whether patients with these sacral resections should be allowed to stand and walk with full weight bearing at an early stage postoperatively Later in the postoperative course there should be less problem as it is well known that a change of loading conditions will induce bone remodeling and adaption of skeletal strength This is generally referred to as Wolff s law In accordance with this law radiographic evidence has been obtained from the patients referred to above to suggest that the strength of the pelvic ring increases with time after the operation (Figure 1)

The anatomy and statics of the sacroiliac region have been described by several authors (e g Schunke 1938 Weisl 1954 Kopsch 1955 Solonen 1957 Hollinshead 1969) The posterior part of the pelvic skeleton can be looked upon as an arch with the base of the lateral pillars in the acetabuli The sacrum which takes up the body load is the key stone of the arch A downward movement of the sacrum is prevented by its wedge shape and the unevenness of the sacroiliac joint surfaces Separation of the pillars is prevented anteriorly by the pubic symphysis and posteriorly by

Table 1 Material and results in experimental study on pelvic strength
Age sex body weight (BW) ultimate compressive load (UCL) calculated load in upright standing (P), excess strength (UCL/P) and diagnosis are given

	No	Age	Sex	BW (kg)	UCL (Newton)	P (Newton)	UCL/P	Diagnosis
Unresected	1	51	F	40	4611	569	8.1	Chronic pyelonephritis bilaterally with uremia + Circulatory insufficiency
	2	50	F	64	3630	883	4.1	Collagenosis + Pulmonary embolism (Steroid treatment last 6 months)
	3	74	M	?normal stature	5297		–	Myocardial infarction + Pulmonary embolism
	4	82	F	44	4905	628	7.8	Advanced arteriosclerosis + Cardiac insufficiency
	5	85	M	60	5837	834	7.0	Bilateral bronchopneumonia + Cerebral arteriosclerosis
				Mean value	4856 (SD 824)			
Resection	6	13	M	?normal stature	5594	–	–	Bronchopneumonia + Hemorrhagic pancreatitis
A	7	60	F	61	1619	844	1.9	Cancer of the uterus + Uremia + Circulatory insufficiency
(below S 1)	8	61	F	50	1079	700	1.5	Aortic aneurysm
	9	68	F	70	> 4905 *	961	> 5.1	Cardioarteriosclerosis + Myocarditis
	10	74	M	14	3237	628	5.1	Advanced cardioarteriosclerosis
				Mean value	3286 (SD 971)			
Resection B (through S 1)	11	29	M	?athletic	5101	–	–	Brain tumor
	12	59	M	76	2315	1040	2.2	Myocardial infarction + Advanced arteriosclerosis
	13	63	F	50	1570	706	2.2	Congestive cardiomyopathy
	14	66	M	80	1962	1099	1.8	Vascular lesion of the brain stem + Advanced cardioarteriosclerosis
	15	69	F	?thin and lean	1472	–	–	Myocardial infarction + Cardioarteriosclerosis
				Mean value	2484 (SD 1500)			

* ultimate value could not be registered on account of technical failure




a b

Figure 1. Lateral radiograms of the L 5–S 1 region of a middle-aged male patient 2 weeks (a) and 2 years (b) after resection of the sacrum through the lower part of the S 1 vertebra. Note the skeletal adjustment: cortical appearance (arrow in b) of the osteotomized, initially cancellous (arrow in a) surface of the S 1 vertebra.

upon in our department. The whole of the sacrum was removed except for the first sacral segment to a varying extent. Adjacent iliac bone was removed on both sides so that the patients lost a large part of the sacroiliac joints and their ligaments. All these patients recovered well from the operation and it was possible to mobilize them to walking, initially with the aid of a stroller or crutches. These observations led to the present study. The purpose was to try to clarify to what degree the pelvis is weakened by a major sacral resection, including various parts of the sacroiliac connections, and to evaluate the retained strength in relation to the estimated normal load. This information should be helpful in determining whether patients with these sacral resections should be allowed to stand and walk with full weight-bearing at an early stage postoperatively. Later in the postoperative course there should be less problem as it is well known that a change of loading conditions will induce bone remodeling and adaption of skeletal strength. This is generally referred to as Wolff's law. In accordance with this law radiographic evidence has been obtained from the patients referred to above to suggest that the strength of the pelvic ring increases with time after the operation (Figure 1).

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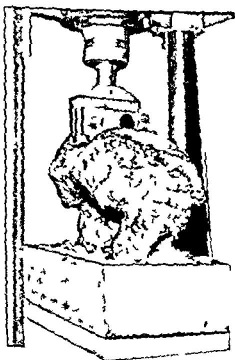
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fairly wide 29-85 years but the age composition of the various groups was quite similar (Table 1) The causes of death were predominantly cardiovascular diseases Two cases of uremia were included (nos 1 and 7) and one patient had received steroid treatment during the last 6 months before death (no 2) It was not possible to establish the exact duration of premortal bed rest from the medical records A major difference in this respect between the various groups was however unlikely

Resection A (Figure 2 darkest fields)

Anteriorly the resection comprised the whole of the sacrum except for the first segment Thus the resection line ran between the bodies of S 1 and S 2 and through the anterior opening of the first sacral holes Posteriorly the resection also comprised parts of the first sacral segment including the posterior opening of the first sacral holes and the entire posterior wall of the sacral canal From each iliac bone a posterior part adjacent to the resected portion of the sacrum was included In this manner about one third of the sacroiliac joint with corresponding ligaments was removed on both sides



F gure 3 I I se up o eu f spec men under test n I I ons

Resection B (Figure 2 less dark fields also included)

Anteriorly the first sacral segment was divided approximately 1 cm below the promontory and superior to the first sacral holes Posteriorly the body of S 1 was divided only a few millimeters

joint with corresponding ligaments remained on each side (anterosuperior part)

METHOD

The ischial tuberosities and the inferior pubic rami of the pelves were fixed in epoxy resin (Plastic Padding®) in a metal box in a position corresponding to upright standing (Boyd et al 1958) The specimens were loaded on the L 5 vertebra in a standard material testing machine Alwetron Model T 2000 with a deformation speed of 5 mm/min (Figure 3) A strain gauge load cell transducer of 9810 N (1000 kp) with an accuracy of ± 1 per cent (according to the manufacturer) was used The load and the time were registered on an x y recorder over a measuring bridge and an amplifier The specimens were x rayed before and after testing

To make it possible to judge the clinical significance of the experimental data the hypothetical load in upright standing was calculated according to Nachemson & Elfstrom (1970) who have shown that the load on lumbar discs in upright standing may be calculated using the formula $P = 8 + 2\,2\,W$ where W is the part of the body weight exerting load upon the disc This has been estimated by Ruff (1950) who found that approximately 60 per cent of the body weight lies above L 3 The calculated loads according to the above formula are given in Table 1

Prior to failure testing two specimens in each group (nos 1 5 9 10 11 13) were loaded one to three times up to approximately twice the estimated normal load in upright standing to find out if any permanent tissue damage occurred with these loads Eventually all specimens were subjected to ultimate compressive loads

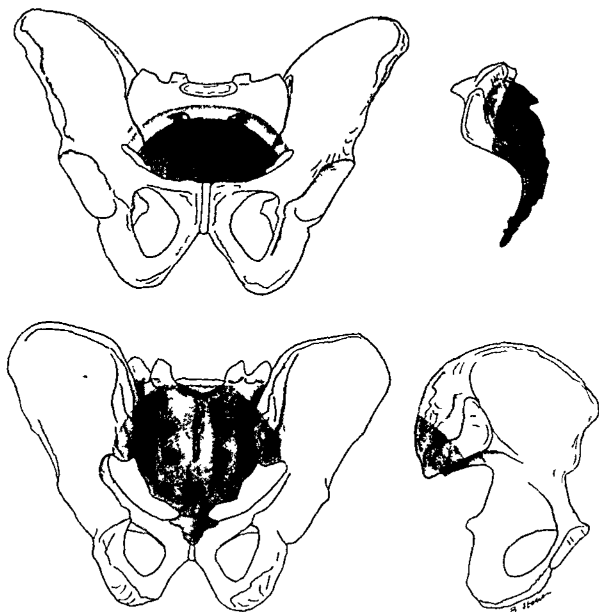


Figure 2 Schematic drawings of resections performed in this study Resection A darkest fields Resection B less dark fields also included

the sacroiliac ligaments The interosseous sacroiliac ligaments also serve as suspensors for the sacrum On vertical loading of the sacrum these ligaments tighten and the posterior parts of the iliac bones are thereby pulled together so that the sacrum is squeezed between them The interosseous sacroiliac ligaments also check the forward downward movement of the upper part of the sacrum which takes place as a result of the vertical load Thus, for several reasons the arch is dependent for its strength on the strong interosseous sacroiliac ligaments

MATERIAL

Fifteen cadaver pelves were used (Table 1) They consisted of the pelvic ring with the fifth lumbar vertebra and had been roughly cleaned of soft tissues with the exception of the ligaments which were left intact The specimens were kept in the deep freeze and were allowed to thaw at room temperature in moist wrappings 12 24 hours before testing This treatment has previously been shown not to alter the physical



Figure 5 Radiograms of specimens showing fracture locali ations The initial fractures are indicated by arrows a Unresected specimen

b Resected specimen (through S 1)



resected specimens was *noted in the* steroid treated patient (no 2)

In this limited material the weakening of the posterior arch *of the pelvis after* Resection A (below S 1) was *approx*imately 30 per cent and after Resection B (through S 1) approximately 50 per *cent*, as calculated from mean values *Informa*tion regarding the normal load *in vivo on the* pelvic ring is needed to evaluate our results and to judge whether *the re*sections *leave* sufficient residual strength *in the* pelvic ring to allow early post*operative* weight bearing It should be borne in mind that the load at a certain vertebral level is greater because of mus-

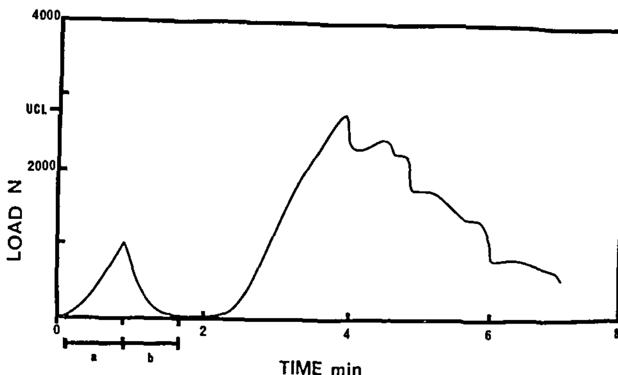


Figure 4 Load-time diagram of specimen no 10 (resection A) Preliminary test to approximately twice the estimated load in upright standing revealed no residual deformation (a = b)

RESULTS

The result of the preliminary tests with loading up to approximately twice the estimated normal load in upright standing did not show any significant residual deformation Thus, the unloading resulted in recovery of the deformation which was about 5 mm

In the test to failure the mean ultimate compressive load in the group of unresected pelves was 4856 N (standard deviation 824 N) The specimens resected according to A had a mean ultimate compressive load of 3286 N (standard deviation 1971 N) and those resected according to B 2484 N (standard deviation 1500 N) The ultimate compressive load of each specimen is given in Table 1 A typical graphic recording of a load test (specimen resected according to A) is shown in Figure 4

All specimens fractured through the lateral part of the sacrum relatively close to the sacroiliac joints, first on one side and then on the other The fracture localization was difficult to observe in the specimens after unloading when the sacrum returned to almost its original position due to the elasticity of the obviously uninjured sacroiliac ligaments If the deformation was allowed to continue well past the point of maximal load the fractures became more obvious and in resected specimens the S 1 vertebra or its remains eventually split Permanent dislocation of the sacroiliac joints did not occur in any specimen Figure 5 shows fracture localization in unresected and resected specimens

DISCUSSION

The sacroiliac junction is very strong Thus, the failure occurred in the lateral parts of the sacrum in unresected as well as resected specimens and the deformation curves also indicated a very low degree of permanent deformation of the soft tissues The lowest value of ultimate compressive load in the group of un-

Acta orthop scand 47 643–647 1976

WEAR OF THE POLYETHYLENE HEAD OF THE OSCOBAL PROSTHESIS

EILIF DAHL & OTTO A MIKKELSEN

Department of Surgery Haugesund Hospital Norway

Ten hemiarthroplasties were performed with the Oscobal (Daubenspeck) hip prosthesis which consists of a metal stem and a non rotating polyethylene head Five patients died 1 150 days after the operation Signs of massive wear of the polyethylene head were demonstrated in four out of the five patients still alive 16–28 months after the operation We can therefore not recommend the Oscobal system for hemiarthroplasty of the hip

Key words femoral neck fractures surgery Oscobal prosthesis wear of polyethylene head

Accepted 30 vi 76

The most suitable primary treatment for displaced femoral neck fractures and the complications involved is still the subject of a lively debate Kaslie et al (1975) found the Christiansen endoprosthesis to be a very good alternative to nailing and Johnson & Crothers (1975) noted fewer failures after replacement with the Moore prosthesis than after nailing Salvati et al (1974) however concluded that the best long term results were still attained by the method that promoted healing of the fracture while preserving the patient s own viable femoral head

For many years in this hospital we have used the Thompson or the Moore prosthesis but only on the basis of relatively limited indications However we wanted a system that could be used equally well for partial and total hip replacement and in 1973 we decided somewhat arbitrarily to try the Oscobal (Daubenspeck) prosthesis

MATERIALS AND METHOD

The Oscobal total hip prosthesis consists of three parts (Figure 1)

1 The standard stem is made of a cobalt chromium molybdenum alloy A conical plug holds the interchangeable head piece and four retaining slots prevent the head rotating
2 The head is manufactured from high molecular weight polyethylene in various sizes 38–54 mm) with various lengths and angulations of the collum
3 The acetabular cup is made of the same alloy as the stem

The approach for insertion of the prosthesis is determined by the preference of the surgeon Acrylic cement is used for fixation of the stem after reaming of the medullary canal and also for fixation of the acetabular cup

The femoral head removed from the acetabulum is measured a provisional head is selected accordingly and the size is checked directly in the acetabulum In order to keep the load per unit surface to a minimum the largest head able to enter the acetabulum is used

cular activity, than the weight of the overlying part of the body Nachemson & Elfstrom (1970) have shown that the load varies depending on posture, movements, etc . ordinary slow walking increases the load by about 15 per cent, jumping on the floor and coughing by about 40 per cent, straining with erect posture by about 50 per cent, and straining with sitting posture by 5–35 per cent

In the cases in which information on the body weight was available (11/15) a good margin was found between the calculated load in upright standing and the load at failure, as seen from the calculated "excess" strength of the specimens in Table 1 (UCL/P) Thus, the test strength was 4–8 times the calculated load in upright standing in the unresected group, 1 5–5 times after Resection A, and approximately twice the calculated load after Resection B

From this study it seems safe, with regard to residual strength of the pelvic ring, to allow patients to stand with full weight-bearing at an early stage postoperatively after submaximal resection of the sacrum including adjacent iliac bone

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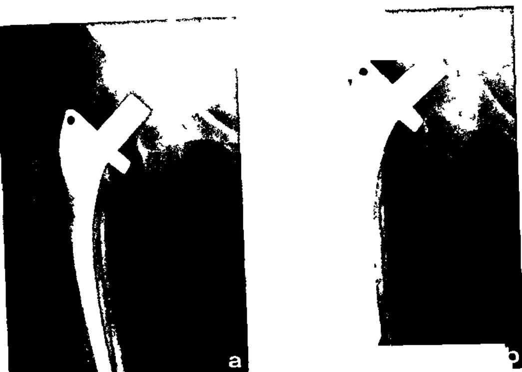


Figure 2 X rays of the same hip taken 19 months apart Note reduced distance between the prosthetic neck and the acetabular floor

died, two of them in this hospital One patient died 24 hours after the operation She had a marked drop in blood pressure (from 180 to 100 mmHg systolic) during and after operation, and ECG showed ischaemic changes The other patient fell out of bed 2 months after the operation and sustained a supracondylar fracture of the operated femur She remained in traction until she died 150 days after the arthroplasty Autopsy was not done in either of the cases

The other three patients died 45 47 and 60 days after the operation At that time they had left the hospital, and the causes of death are not known

The remaining five patients were re examined 16 28 months after the arthroplasty At that time all of them needed various forms of walking support, experiencing some discomfort in the hip In all the patients there were roentgenological signs of osteolysis around the cement, and in four patients the distance between the neck of the prosthesis and the acetabular floor was reduced, indicating wear of the prosthetic head (Figure 2) In one patient this was noted as early as 16 months after the operation The only patient in whom roentgenological signs of wear were still absent had an almost immobile hip joint, because of voluminous periarticular calcification 1 5 years after arthroplasty

So far two patients have been reoperated, and a marked abrasion of the polyethylene head has been found (Figure 3) Macroscopically the acetabular cartilage seemed intact, but the capsule was thickened, and the joint contained an excess of serous fluid Necrotic-appearing tissue was found around the proximal part of the stem, and in one case the stem was



Figure 1 The Oscobal (Daubenspeck) total hip prosthesis Provisional head with standard stem and cup

RESULTS

Over a 16-month period ten hemiarthroplasties with the Oscobal prosthesis were performed, all were female patients and the indications are outlined in Table I The mean age at operation was 83 years (range 73 94) After only 19 months we had to replace the first head piece due to abrasion, and as we had received reports of the same complication from the manufacturer, we decided to discontinue the use of this prosthesis for the time being and to review the previous cases

In five patients an antero lateral and in five patients a postero-lateral approach had been chosen No remodelling of the acetabulum had been necessary All operations except one were uneventful Postoperative X-rays were satisfactory in all patients, showing the prostheses to be in their proper place and no fractures of the femoral shaft to have occurred Hence, unrestricted weight-bearing was permitted within a few days From the time of admission all patients received low dose heparin thromboprophylaxis (5000 IU subcutaneously every 12 hours)

Table 1 Indications for operation

Elderly and weak patients with severely displaced fractures	6
Primary nailing with later dislocation	3
Aseptic necrosis of the femoral head after nailing	1
Total	10

Following the operation five patients

The patient material is small and the observation period short but still the rather uniform results illustrate clearly that the Oscobal system should not be used for hemiarthroplasty of the hip, because of the risk of considerable abrasion of the polyethylene head

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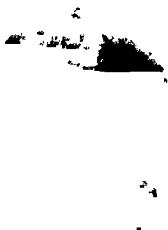


Figure 3 Polyethylene head removed 19 months after hemiarthroplasty

loose Cultures were negative, and histological examinations showed bone, cartilage and fibrous tissue with a massive *foreign body reaction*

DISCUSSION

The advantage of the Oscobal prosthesis is that the head piece is easily interchanged By subsequently adding a standard cup an existing replacement femoral head can be expanded to a complete total hip joint replacement, without having to remove the standard stem from its position In order to ensure the desired sliding motion between the inner cup surface and the head surface, the femoral head is prevented from rotating by cams in the stem

According to the manufacturer, the special *Oscobal femoral head mounting* results in less wear than the rotating mounting of a head on a small diameter plug In total prostheses Scales (1973) also found it preferable to have a simple ball and socket type of joint, since there is a risk that undue wear of the components can occur when the ball is designed to rotate on an axle In Webers rotation-endoprosthesis for total hip replacement, however, the rate of wear in the cylindrical hole of the rotation ball has been greatly reduced thanks to an optimized surface treatment of the AP polyester After more than 2 years use minimal wear was noted only in the *cylindrical hole* as a widening of the boring near the apex of the trunnion, while the original geometry of the joint was maintained (Weber & Semlitsch 1973)

Willert (1973) stated that products of wear can be found consistently, but in varying quantities, in the periarticular tissues of arthroplasties using plastic components Kavlie et al (1975) found, in some cases, considerable abrasion of the plastic head of Christiansen rotation hemiprosthesis This problem has apparently been eliminated following the coating of the head with a thin steel cap (introduced in 1968).

Abrasion of the surface of the head usually occurs when the head is too small or the acetabulum has not been properly remodelled In all the patients in the present material the head initially fitted very well into an intact acetabulum We have found strong correlation between abrasion of the head and roentgenological signs of osteolysis of the stem Reasons for osteolysis might be micromovements of the stem from friction due to abrasion of the head piece and a foreign body synovitis (Kavlie et al 1975, Christiansen 1974) Other authors have discussed thermal necrosis and subsequent bone resorption (e g Feith 1975) and metal toxicity (e g *Jones et al 1975*) as causes of symptoms after arthroplasties

The high mortality rate in this age group is not unexpected (Mikkelsen & Langholm 1964) In the present material a definite selection has been made of frail and elderly persons



gure 1 Case 1 (I H) at four weeks old Hypoplas a of the femur absence of the bones n the lower leg ban l like bony density lateral n the area of the femoral con lyles with a separate center of oss fication

On the lateral X ray there is an exostotic th ckening of the distal femur at the level of the popl teal fossa The X rays at the age of 12 show that this exostosis used to possess its own growth center

Case 2 is a Turkish boy (Y M) who was first examined at our hospital at the age of three

Cl n cally the left th gh showed a club like enlargement of the lower third (Figures 5 a and b) The lower leg was shortened and hypoplastic with a fixed deform ty of 90 degrees in relation to the th gh The foot was hypoplastic as well with the fourth and fifth rays missing The patella was absent but the fibula was present The lateral malleolus could be felt through the skin the medial malleolus was missing Prox imal to the crural joint a club l ke structure was found and distal to this bony structure there was a palpable thickening which clinically seemed to be the tibia

X ray exam nation revealed a b furcation of the femur at the junction between middle and distal third (Figures 6 a and b) The lateral segment is in alignment with the axis of the femur and articulates with the fibula The medial segment deviates in a mediod rsal direc



Figure 2 Case 1 (P H) at 12 years ol l lateral X ray of knee joint complex



Figure 3 Case 1 (P H) at 33 years old sky line view of right patella with hypoplasia of the me lial femoral condyle

Acta orthop scand 47, 648 652 1976

BIFURCATION OF THE DISTAL FEMUR

W KUSSWETTER, K A MATZEN & D BAUMANN

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Bifurcation of the femur has previously been reported in the literature in only 12 cases Two more cases are added and the etiology of this congenital anomaly is discussed

Key words congenital malformation femoral bifurcation foot aplasia, tibial aplasia

Accepted 22 ix 76

Bifurcation of the distal femur is a rare congenital anomaly It has been described only in conjunction with an ipsilateral absence of the tibia

CASE REPORTS

Case 1 is a 33 year old male patient (P H) who was admitted to our hospital for the first time when he was 4 weeks old His parents had noted an extreme shortening of the right lower leg at birth An X ray examination showed complete absence of the tibia and fibula and hypoplasia of the femur

In the area of the femoral condyles the X rays (Figure 1) revealed laterally a narrow dense band like structure with a separate center of ossification In contrast to the normal left side the right hind foot showed only one center of ossification There was also absence of the fibular ray of the right foot with simultaneous hypoplasia of the third metatarsal

Clinically and radiologically this was a complete paraxial hemimelia with aplasia of tibia and fibula but with the tibial ray of the foot present

Follow up at age 12 showed only a slight growth retardation of the right femur in comparison with the normal left leg Radiologically (Figure 2), there is a bifurcation of the distal femur and presence of a dysplastic patella *Distal to* the femoral condyles a compact bone is visible on the X rays This bone fragment could be palpated clinically The patellar ligament could actively extend it In accordance with its topographic location and function this can only be the dysplastic tibia The bony elements of the hind foot consist of a y shaped ossicle the cuboid the navicular and the first cuneiform

No attempt was made at surgical correction The patient was fitted with a femoral prosthesis On his last visit at the age of 33 the right thigh was only slightly shorter and thinner than the left Immediately below the knee joint the foot was placed in extreme equinus and had a slight external rotation The range of motion of the foot was limited to 20 degrees dorsiflexion from an extreme equinus position The lateral femoral condyle was smaller than the medial A bony prominence was palpable in the popliteal fossa The patella much smaller than on the left side was freely movable The knee joint was slightly rotated externally When the quadriceps contracted the patella could be elevated and the foot could be extended 20 degrees deviating slightly to the lateral side

The X ray demonstrates a hypoplasia of the medial femoral condyle (Figure 3) Distal to the lateral condyle is a bony structure with an oblique direction towards medial The bones of the hind foot which have become fused are located medially to this bony structure (Figures 4 a and b) There is an articulation between the hind foot and the fore foot The first cuneiform has fused to the navicular The first second and fourth toes appear almost normal The third metatarsal is short and small and the fifth toe is missing It cannot be determined whether the aplasia affects the fourth or fifth ray



Figure 1 Case 1 (P.H.) at four weeks old Hypoplasia of the femur absence of the bones of the lower leg band like bony density lateral in the area of the femoral condyles with a separate center of ossification

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Follow up at age 12 showed only a slight growth retardation of the right femur in comparison with the normal *left leg Radiologically* (Figure 2) there is a bifurcation of the distal femur and presence of a dysplastic patella Distal to the *femoral condyles* a compact bone is visible on the X rays This bone fragment could be palpated clinically The patellar ligament could actively extend it In accordance with its topographic location and function this can only be the dysplastic tibia The bony elements of the hind foot consist of a y shaped ossicle the cuboid the navicular and the first cuneiform

No attempt was made at surgical correction The patient was fitted with a femoral prosthesis On his last visit at the age of 33 the right thigh was only slightly shorter and thinner than the left Immediately below the knee joint the foot was placed in extreme equinus and had a slight external rotation The range of motion of the foot was limited to 20 degrees dorsiflexion from an extreme equinus position The lateral femoral condyle was smaller than the medial *A bony* prominence was palpable in the popliteal fossa The patella much smaller than on the left side *was freely movable The knee joint was slightly* rotated externally When the quadriceps contracted the patella could be elevated and the foot could be extended 20 degrees deviating slightly to the lateral side

The X ray demonstrates a hypoplasia of the medial femoral condyle (Figure 3) Distal to the lateral condyle is a bony structure with an oblique direction towards medial The bones of the hind foot which have become fused are located medially to this bony structure (Figures 4 a and b) There is an articulation between the hind foot and the fore foot The first cuneiform has fused to the navicular *The first second* and fourth toes appear almost normal The third metatarsal is short and small and the fifth toe *is missing It* cannot be determined whether the aplasia affects the fourth or fifth ray



Figure 1 Case 1 (P.H.) at four weeks old Hypoplasia of the femur, absence of the bones in the lower leg band like bony density lateral in the area of the femoral condyles with a separate center of ossification

On the lateral X ray there is an exostotic thickening of the distal femur at the level of the popliteal fossa. The X rays at the age of 12 show that this exostosis used to possess its own growth center

Case 2 is a Turkish boy (Y M) who was first examined at our hospital at the age of three

Clinically the left thigh showed a club like enlargement of the lower third (Figures 5 a and b) The lower leg was shortened and hypoplastic with a fixed deformity of 90 degrees in relation to the thigh. The foot was hypoplastic as well with the fourth and fifth rays missing. The patella was absent but the fibula was present The lateral malleolus could be felt through the skin the medial malleolus was missing. Proximal to the crural joint a club-like structure was found and distal to this bony structure there was a palpable thickening which clinically seemed to be the tibia

X ray examination revealed a bifurcation of the femur at the junction between middle and distal third (Figures 6 a and b) The lateral segment is in alignment with the axis of the femur and articulates with the fibula The medial segment deviates in a mediodorsal direc



Figure 2 Case 1 (P.H.) at 12 years old lateral X ray of knee joint complex



Figure 3 Case 1 (P.H.) at 33 years old sky line view of right patella with hypoplasia of the medial femoral condyle



a



b

Figures 4 a and b Case 1 (P H), at 33 years old (a) a p and (b) lateral X-rays of the right femur knee-joint complex, and foot

tion This segment has a growth plate while the lateral does not The fibula lacks a growth plate in its proximal part and there is no tibial growth plate The skeleton of the foot contains the osseous nuclei of talus calcaneus and cuboid The three lateral digital rays are present

Both cases were treated conservatively The first patient is well adjusted to his femoral prosthesis The active mobility of the knee joint' complex enables good function and an acceptable gait The patient has a sedentary occupation

The second case was treated with a Thomas splint to enable an upright gait We await further development of the malformation By resection of the useless part of the bifurcation and the lower leg we will then have better conditions for proper treatment with a prosthesis

DISCUSSION

During the past 100 years, occasional reports have been made about bifurcation of the femur, usually in connection with aplasia of the tibia The first case of bilateral femoral bifurcation was reported by Ehrlich (1885) Liepman (1906) was the first to present X-rays of this deformity with reference to a case observed by Hildemann (1882) The following authors have each contributed one case Rodriguez & Escardo (1924), Nigst (1927), Cornah & Dangerfield (1974) and Ogden (1976) The largest series was collected by Aletter (1932) with 5 cases

In 1960, Salzer reported the case of a patient who had a femoral exostosis at the same location as our first case In contrast to our patient, this patient lacked the patella Thirteen of the 183 cases of aplasia of the tibia collected by Salzer showed such a femoral exostosis



a b

F g res 5 a and b Case 2 (V M) at 3 years old clinical pictures f left extremity malformati n

He concluded that this was an ectopic anlage of the tibia since a femoral exos tosis in this location had never been described with a partial tibial defect Ehrlich (1885) had offered the same explanation after dissection of a bilateral femoral bifurcation The specimen con tained no patella and the insertions of gracilis sartorius semimembranosus and semitendinosus muscles led to one of the shafts of the femoral bifurcation Ehrlich considered that this was there fore a heterotopic development of the tibia

In contrast our first case has a patella and a patellar ligament enabling an ac tive dorsiflexion of the foot in the knee joint This together with the orthograde position of the foot gives rise to the thought that there must be a hypoplastic tibia (Figures 5 a and b)

The second case has a striking resem blance to the most recently reported case by Ogden (1976) The femur shows a bifurcation rather than a reduplication as described in the case of Cornah & Dangerfield (1974) The singular bone of the lower leg definitely represents the fibula Radiologically, we are therefore dealing with a complete tibial aplasia This however, is not in accordance with the clinical picture of an orthograde position of the foot in cases of aplasia of the tibia the foot should be in an equinus position The only possible explanation is that the foot has been held in an ortho grade position by a cartilaginous tibial anlage not visible on X ray

From our two observations we con clude that bifurcation of the femur can not be considered an ectopic tibial an lage Femoral bifurcation appears only in



a b

Figures 6 a and b Case 2 (V M) at 3 years old (a) ap and (b) lateral X rays of left lower extremity

conjunction with malformation or aplasia of one of the bones of the lower leg

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Acta orthop scand 47, 653–657, 1976

OLD TOTAL RUPTURE OF THE ADDUCTOR LONGUS MUSCLE

A Report of Seven Cases

LARS PETERSON & BERTIL STENER

Department of Orthopaedic Surgery II Sahlgren Hospital University of Gothenburg Sweden

Seven cases of old total rupture of the adductor longus muscle are described Five patients were referred with the suspicion of a soft tissue tumour Six patients reported an adequate trauma when thoroughly questioned, four of them had sustained the injury while playing soccer, the seventh patient could not recall any trauma The diagnosis of this lesion is discussed

Key words adductor longus rupture sports injury soft tissue tumour

Accepted 26 viii 76

…nce 1967, seven cases of old total rup…re of the adductor longus muscle have …en diagnosed at our clinic Five of …ese patients were referred with the …spicion of a soft tissue tumour Total …pture of the adductor longus seems to …e relatively rare and this may be one of …e reasons why the ensuing chronic con…ition sometimes is misjudged To our …nowledge only a few cases of this lesion …ave been reported (Boord 1598, cited by …avidson 1918 Abbe 1895, Davidson …918, O'Donoghue 1970)

The adductor longus muscle arises from the pubis and inserts on the middle third of the linea aspera on the dorsal aspect of the femur The muscle is much broader at its insertion than at its origin On the anterior aspect of the thigh Figure 1) the sartorius, pectineus and gracilis muscles are the immediate neigh bours of the adductor longus

CASE REPORTS

Case 1 A 23 year-old man was referred with the suspicion of a tumour in the right thigh Four years earlier he had sustained a trauma while playing soccer He had been kicking the ball with the medial side of the foot at the same time as an opponent had tried to kick the ball in the opposite direction i e an impact had been directed against the leg forcing it into abduction at the same time as the adductor muscles in the thigh strongly contracted coun teracted such a motion When he came for con sultation 4 years after the injury a prominence was visible in the upper medial part of the thigh (Figure 2) and corresponding to this an indolent soft mass was palpated Distal to this a defect could be felt When the patient tried to adduct the leg against resistance the mass changed its form and consistency, it became more rounded and firmer Furthermore its lower border was retracted higher up and at the same time the defect distal to it between the sartorius and gracilis muscles, became more obvious (Figure 3) This confirmed the diag nosis of an old muscle rupture and taking into consideration the topographic anatomy (com pare with Figure 1) it was concluded that it was the adductor longus that had been ruptured The patient suffered no discomfort of import





a b

Figures 6 a and b Case 2 (V M), at 3 years old, (a) a p and (b) lateral X rays of left lower extremity.

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Since 1967, seven cases of old total rupture of the adductor longus muscle have been diagnosed at our clinic Five of these patients were referred with the suspicion of a soft tissue tumour Total rupture of the adductor longus seems to be relatively rare and this may be one of the reasons why the ensuing chronic condition sometimes is misjudged To our knowledge only a few cases of this lesion have been reported (Boord 1898 cited by Davidson 1918 Abbe 1895 Davidson 1918 O Donoghue 1970)

The adductor longus muscle arises from the pubis and inserts on the middle third of the linea aspera on the dorsal aspect of the femur The muscle is much broader at its insertion than at its origin On the anterior aspect of the thigh (Figure 1) the sartorius pectineus and gracilis muscles are the immediate neighbours of the adductor longus

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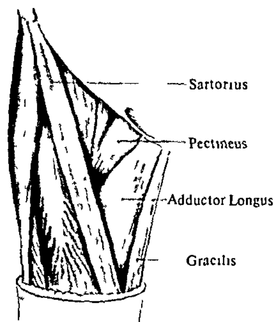


Figure 1 Topography of the adductor longus muscle

ance and as the diagnosis of a tumour could be refuted there was no indication for treatment

Case 2 A 31-year old man was referred with the suspicion of a tumour in the right thigh Seven months earlier he had sustained a trauma similar to that in Case 1 while playing soccer He had felt a sudden pain in the medial part of the thigh and some days later he had noticed a blue green discoloration in the same place One month later he had noticed a swelling for the first time At examination under muscle relaxation there was a discrete prominence medially below the groin its consistency was soft Under isometric active adduction of the thigh a rounded prominent lump appeared which felt firm on palpation Furthermore an aponeurotic band extending from the lump down to the femur could be felt within the angle formed by the sartorius and gracilis muscles It was con

Figures 2 and 3 Case 1 Right thigh during muscle relaxation (Figure 2) and with the adductors contracted (Figure 3) Notice in Figure 3 the triangular defect delimited by the ruptured adductor longus and the sartorius and gracilis muscles (compare with Figure 1)

Figures 4 and 5 Case 3 Right thigh during muscle relaxation (Figure 4) and with the adductors contracted (Figure 5)

cluded that the adductor longus muscle having retracted proximally after a total distal rupture eventually had made a new attachment to the femur via the formation of scar tissue As the patient was free from discomfort no treatment was called for

Case 3 A 34 year old man was referred with a suspected soft tissue tumour in the upper medial part of the right thigh In a soccer game one and a half years earlier he had sustained a trauma similar to that in Cases 1 and 2 He was rather fat and palpation was difficult but the medial contour of the thigh became more prominent during isometric active adduction of the thigh (compare Figures 4 and 5) It seemed to be an old rupture of the adductor longus muscle and support for this diagnosis was obtained by a soft tissue radiography which demonstrated that this muscle became more rounded at the same time as its distal pole moved proximally during attempted adduction of the thigh against resistance (compare Figures 6 and 7) The diagnosis was then confirmed by needle electromyography of the suspected tumour Figure 8

Case 4 A 25 year-old man sustained a trauma similar to that in Cases 1 2 and 3 while *playing* soccer He felt sudden pain in the medial part of the thigh About 1 month later he *noticed* a



Figures 6 and 7 Case 3 Soft tissue radiographs of the upper medial part of the right thigh during muscle relaxation (Figure 6) and with the adductors contracted (Figure 7) The contour of the ruptured adductor longus muscle is marked by arrows



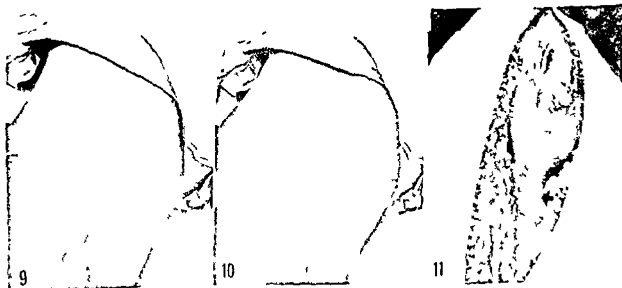
Figure 8. Case 3. Electromyography of the ruptured muscle.

swelling medially below the groin. When he came for consultation one and a half years after the trauma he reported that the swelling had slowly increased in size. At examination the swelling felt soft during muscle relaxation (Figure 9) but became firm, rounded and prominent during attempted adduction of the thigh against resistance (Figure 10). On deep palpation distal to the rounded lump one could feel a broad fibrous band having the same orientation as the adductor longus muscle has normally. As the patient experienced pain during exercise it was decided to explore the lesion. At the operation it could be concluded that the adductor longus muscle after a total distal rupture had retracted proximally and then become re-attached to the femur by the formation of aponeurotic scar tissue (arrow in Figure 11). The nerve to the muscle had a recurrent course and was surrounded by scar tissue which possibly was the reason for the pain during exercise. The muscle was extirpated. At follow-up examination 5 years after the operation the patient was free from discomfort and could adduct both thighs with equal force.

Case 5. A 26-year-old man came for consultation because of a swelling in the upper medial part of the left thigh. Four weeks earlier he had been hit by a heavy bale of paper which had fallen down between his legs and forced the left leg into abduction. During muscle relaxation a soft mass could be palpated at the site of the adductor longus muscle. On isometric active adduction of the thigh it became firmer, rounded and more prominent. Taking into consideration the history and the topography and behaviour of the mass a rupture of the adductor longus muscle was diagnosed. As the patient was free from discomfort there was no need for treatment.

Case 6. A 15-year-old boy was referred with a suspected soft tissue tumour in the upper medial part of the right thigh. Three months earlier while riding a motorbike on a stony forest road he had felt a sudden pain medially in the thigh. About 1 month later he noticed a swelling at the site of the adductor longus muscle. Palpation revealed an indolent soft mass which became firm, rounded and more prominent when the patient actively resisted abduction of the thigh. At the same time an aponeurotic band extending down to the femur could be palpated in the defect which was present distal to the mass between the sartorius and gracilis muscles. Needle electromyography showed normal muscle activity and confirmed the diagnosis of muscle rupture. He had no discomfort calling for any treatment.

Case 7. A 36-year-old man was referred with a suspected soft tissue tumour in the upper



Figures 9, 10 and 11. Case 4. Right thigh during muscle relaxation (Figure 9) and with the adductors contracted (Figure 10). Figure 11. Lesion surgically explored. The ruptured muscle has retracted and its lower pole has become reattached to the femur by an aponeurotic band of scar tissue (arrow).

medial part of the right thigh He could not recall any relevant trauma On palpation an old rupture of the adductor longus muscle was suspected but the clinical picture was not altogether clear Angiography was performed showing a normal vascular pattern To confirm the diagnosis operative exploration was undertaken It was found that the adductor longus muscle after a total distal rupture had retracted proximally and then eventually become reattached to the femur by aponeurotic scar tissue The lesion was not treated and at follow up examination one and a half years later the patient was free from discomfort

DISCUSSION

In cases with a tumour-like swelling high up in the medial part of the thigh an old total rupture of the adductor longus muscle should be considered as a possibility and the patient should be questioned regarding the occurrence of an adequate trauma prior to the appearance of the swelling Out of the seven patients six recalled that they had sustained such a trauma four of them while playing soccer the seventh had forgotten the injury he obviously must have suffered It is interesting that a total rupture of the adductor longus muscle can occur without causing much trouble for the patient This observation is in accordance with the well known fact that after a total rupture of a ligament pain is usually less pronounced than after a partial rupture Only one patient complained of pain when exercising The others suffered no discomfort from the rupture in the inveterate stage

One important differential diagnosis is intramuscular lipoma (Kindblom et al 1974) This tumour has in common with the muscle rupture the sign that the palpable mass becomes firmer in consistency and more rounded in shape during muscle contraction A difference is that a defect can usually be palpated at the site of the muscle rupture when comparing with the unaffected leg To some extent the defect may be replaced by fibrous scar tissue In several of our cases such tissue had become organized into an aponeurotic band serving as a new tendon for the ruptured muscle Soft tissue radiographs, sometimes including tomography, is of value in distinguishing intramuscular lipoma from muscle rupture because of the difference in roentgen absorption between adipose and muscle tissue

In five of the seven cases the patient was referred with the suspicion of a soft tissue tumour, which is not surprising as the patients had noticed a growing mass This increase in size is probably due to a compensatory hypertrophy of the ruptured muscle taking place because, having retracted after the rupture, the muscle has to work with the disadvantage of the shortened distance between its origin and the new insertion created by scar tissue

The diagnosis of old total rupture of the adductor longus muscle is not difficult after thorough questioning and clinical examination taking into consideration function and topographic anatomy

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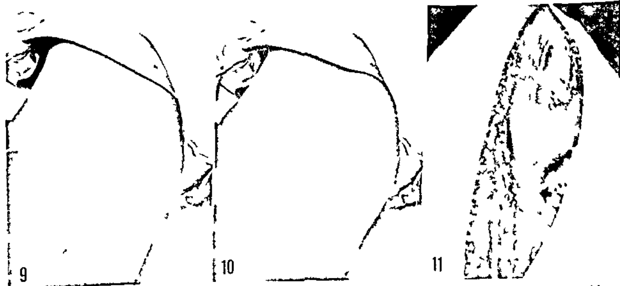
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Acta orthop scand 47, 658–663 1976

KNEE INSTABILITY

An Orthoradiographic Study

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An orthoradiographic method for preoperative assessment of medio lateral instability and varus/valgus deviation in gonarthrosis is presented A special definition of the varus/valgus deviation is given The examination technique has been tested on 15 young healthy subjects with no clinical signs or symptoms in their knee joints To test the accuracy of the method, seven of the subjects were re examined at a later date

Key words knee instability measurement, orthoradiographic method normal subjects

Accepted 26 viii 76

In the operative correction of valgus or varus deformities in gonarthrosis by means of wedge osteotomy, the size of the wedge is generally determined by some form of preoperative radiographic examination A common technique is to take a frontal view of the knee on a large film, usually 40 cm in length The exposure is usually made with the patient standing so as to obtain a picture of the leg in a "functional" position Normally there is a valgus deviation between the axes of the femur and tibia of approximately 7° and the aim of corrective osteotomy is to restore this value (angle) This method is open to criticism on several counts, the most serious of which is that the film does not show the whole leg This is likely to introduce errors in the measurement due to inaccurate placing of the axes of the femur and tibia and to inexactness in the estimation of the normal angle between the femur and tibia in the individual patient

There is a better method which uses a special film (usually 90 cm in length) long enough to include the whole leg from the hip joint to the ankle with the patient standing (Leger 1960, Weinreich 1961, Oest & Sieberg 1971, Spirig 1967) A line can now be drawn on the film from the centre of the femoral head to the centre of the ankle joint It is generally believed that this hip-ankle line should pass the centre of the knee in the middle of the intercondylar eminence Any deviation from this is recorded as a varus or valgus deviation according to whether the line passes medially or laterally to the centre of the knee This method enables a more accurate evaluation to be made but it is necessary to use a technique that will ensure a correct exposure for the various thicknesses of

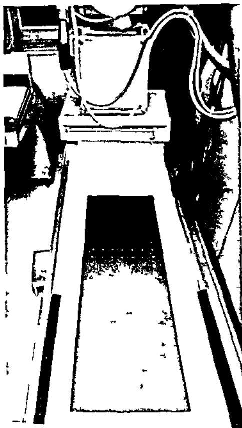


Figure 1 The co ord nate grid place l on the invest gat on table

the leg For this purpose some kind of compensating filter has to be used

Both methods suffer from the dis advantage that if there is medio lateral instability of the knee the joint will not always assume the same position when loaded Moreover no impression of the magnitude of the medio-lateral instabil ity is obtained Therefore we have worked out a method for preoperative examination in gonarthrosis that in cludes determination of both the varus valgus deviation and the medio-lateral instability

METHOD

In true orthoradiography the image should be pr l ced by parallel rays This has the ad vantage over the usual divergent projections that distances parallel to the plane of the film are not enlarged and can therefore be measured directly on the film In radiographic projections an attempt is usually made to reduce the diver gence of the rays as much as possible by using as large a focus to film distance as is con sistent with the conditions for the examination Another advantage of the orthoradiographic projection is that the image of three dimen sional objects does not suffer from the dis tortion present in images produced by divergent projections A number of techniques have been designed that are in some respects ortho radiographic but none gives a truly ortho radiographic projection

The aim of our method is to obtain ortho radiographic projections of individual points on the leg by using three ordinary projections centred over 1) the centre of the femoral head 2) the centre of the knee and 3) the centre of the

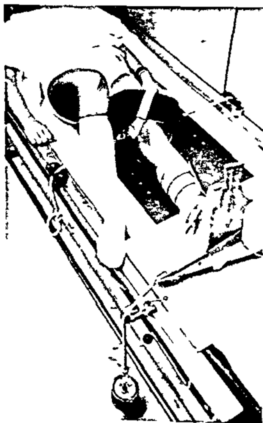


Figure 2 The patient in place on the co-ordinate grid The foot is placed in the boot like device and the varus position is induced with a 5 kg we ght seen in the lower part of the picture

Acta orthop scand 47, 658–663, 1976

KNEE INSTABILITY

An Orthoradiographic Study

PAUL EDHOLM, OLOV LINDAHL, BERNT LINDHOLM, RUNE MYRNERTS, KARL-ERIK OLSSON & ERIK WENNBERG

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An orthoradiographic method for preoperative assessment of medio lateral instability and varus/valgus deviation in gonarthrosis is presented. A special definition of the varus/valgus deviation is given. The examination technique has been tested on 15 young healthy subjects with no clinical signs or symptoms in their knee joints. To test the accuracy of the method, seven of the subjects were re-examined at a later date.

Key words: knee instability, measurement, orthoradiographic method, normal subjects

Accepted 20 viii 76

In the operative correction of valgus or varus deformities in gonarthrosis by means of wedge osteotomy, the size of the wedge is generally determined by some form of preoperative radiographic examination. A common technique is to take a frontal view of the knee on a large film, usually 40 cm in length. The exposure is usually made with the patient standing so as to obtain a picture of the leg in a "functional" position. Normally there is a valgus deviation between the axes of the femur and tibia of approximately 7° and the aim of corrective osteotomy is to restore this value (angle). This method is open to criticism on several counts, the most serious of which is that the film does not show the whole leg. This is likely to introduce errors in the measurement due to inaccurate placing of the axes of the femur and tibia and to inexactness in the estimation of the normal angle between the femur and tibia in the individual patient.

There is a better method which uses a special film (usually 90 cm in length) long enough to include the whole leg from the hip joint to the ankle with the patient standing (Leger 1960, Weinreich 1961, Oest & Sieberg 1971, Spirig 1967). A line can now be drawn on the film from the centre of the femoral head to the centre of the ankle joint. It is generally believed that this hip-ankle line should pass the centre of the knee in the middle of the intercondylar eminence. Any deviation from this is recorded as a varus or valgus deviation according to whether the line passes medially or laterally to the centre of the knee. This method enables a more accurate evaluation to be made, but it is necessary to use a technique that will ensure a correct exposure for the various thicknesses of

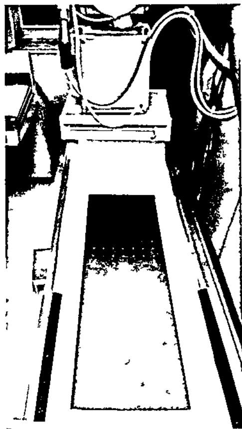


Figure 1 The co-ordinate grid placed on the investigation table

the leg For this purpose some kind of compensating filter has to be used

Both methods suffer from the disadvantage that if there is medio-lateral instability of the knee the joint will not always assume the same position when loaded Moreover no impression of the magnitude of the medio lateral instability is obtained Therefore we have worked out a method for preoperative examination in gonarthrosis that includes determination of both the varus valgus deviation and the medio-lateral instability

METHOD

In true orthoradiography the image should be produced by parallel rays This has the advantage over the usual divergent projections that distances parallel to the plane of the film are not enlarged and can therefore be measured directly on the film In radiographic projections an attempt is usually made to reduce the divergence of the rays as much as possible by using as large a focus to film distance as is consistent with the conditions for the examination Another advantage of the orthoradiographic projection is that the image of three dimensional objects does not suffer from the distortion present in images produced by divergent projections A number of techniques have been designed that are in some respects orthoradiographic but none gives a truly orthoradiographic projection

The aim of our method is to obtain orthoradiographic projections of individual points on the leg by using three ordinary projections centred over 1) the centre of the femoral head 2) the centre of the knee and 3) the centre of the

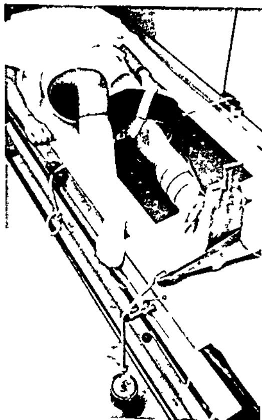


Figure 2 The patient in place on the co ordinate grid The foot is placed in the boot like device and the varus position is induced with a 5 kg weight seen in the lower part of the picture



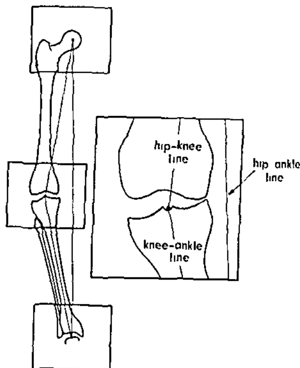


Figure 3 Left The three films from the varus induced position in place on the model of the grid for measurement Above Drawing showing the three lines between the three reference points

ankle joint Each projection is recorded on a separate film A co ordinate grid made of radio translucent material with readily identifiable symbols has been constructed (Figure 1) This grid is placed under the patient's leg and is depicted at the same time as the points of measurement on the separate films We have called *our technique three point measurement* and it is performed in the following manner

The patient is placed on the grid on an examination table The knee is bound to the table with a tight bandage round the lower part of the thigh and the thigh is secured with two cords that are fastened to sheet clips fixed to the edges of the table A 10 kg weight is placed over the knee to keep it in the extended position The foot and lower leg are held in a boot like device mounted on a movable plate, furnished with wheels which allows varus and valgus deviations of the knee joint Under this plate a sheet of glass is placed to reduce friction A cord from the boot is placed medially over a pulley and loaded with a 5 kg weight in the varus inducing position (Figure 2) In this position three separate projections are taken with the orthoradiographic technique one each over the centres of the femoral head the intercondylar eminence and the ankle joint The weight and the cord are then moved to the lateral side the valgus position is induced and three more films are exposed The two sets of three films are then placed on a full scale

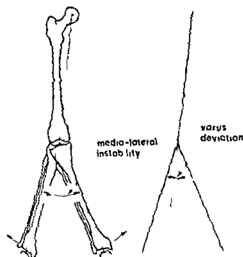


Figure 4. Drawing showing the measurement of the medio-lateral instability and the deviation of the knee.

model of the grid and lines are drawn between the three reference points (*Figure 3*). On each of the two films of the knee three lines are drawn: *the hip-ankle line* from the centre of the femoral head to the centre of the ankle, *the hip-knee line* from the centre of the femoral head to the centre of the tibial eminence, and *the knee-ankle line* from the centre of the eminence to the centre of the ankle. The *medio-lateral instability* is measured as the angle through which the knee-ankle line has moved in relation to the hip-knee line between the two measurements. The varus or valgus deviation of the knee is defined as the angle between *the hip-knee line* and *the middle position* of the knee-ankle line, i.e. the bisector of the instability angle. If this bisector makes a medial deviation, it is regarded as a varus deviation, and if it makes a lateral deviation it is a valgus deviation (*Figures 4 and 5*). The value of this deviation is used when determining the size of the wedge for corrective osteotomy (Edholm et al. 1977).

Figure 5. The knee films with the lines drawn. The medio-lateral instability is 5°. The deviation is [illegible]° varus.

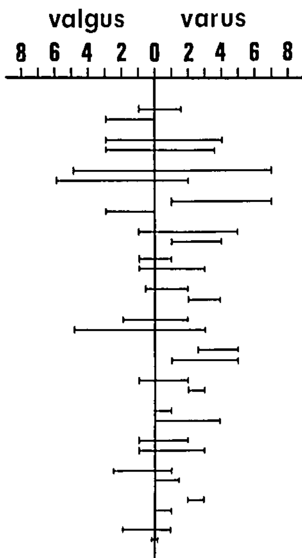


Figure 6. The medio-lateral instability of the 15 subjects.

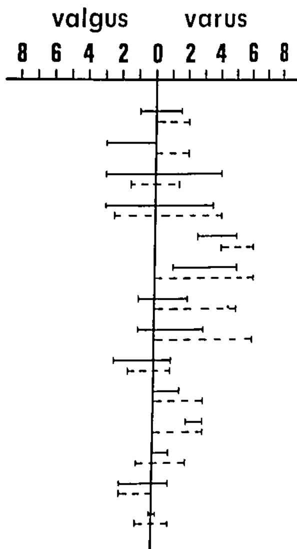


Figure 7. The medio-lateral instability of 14 knees examined on two different occasions. The second examination is represented by broken lines.

SUBJECTS AND RESULTS

In order to test 1) the examination technique, 2) the normal instability of the knee and 3) the hypothesis that the hip-ankle line normally passes through the intercondylar eminence, 15 young healthy subjects with no clinical signs or symptoms in their knee joints were examined with this technique on both knees, i.e., 30 knees were investigated. The results are presented in Figure 6. The results showed that the medio-lateral instability varied between 0° and 12°, with a mean value of 3.7° (standard deviation 2.6°, standard error of the mean 0.5°). The varus/valgus deviation as defined above varied between 1.5° valgus and 4.0° varus with a mean value of 0.9° varus (standard deviation 1.5°, standard error of the mean 0.3°). This small mean value of 0.9° varus means that the hypothesis that the hip-ankle line on the average passes through the centre of the eminence may be considered as confirmed.

To test the accuracy of the method, seven of the subjects (i.e. 14 knees) were re-examined at a later date. The results

of the two examinations are compared in Figure 7 The greatest difference in medio-lateral instability was 4°. The mean differnce in instability between the two occasions was 1 5° The greatest difference in the measurement of the varus/valgus deviation between the two occasions was 2 5° with a mean value of 0 9°

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Acta orthop scand 47 664-667, 1976

THE INCIDENCE OF OSTEOCHONDRITIS DISSECANS IN THE CONDYLES OF THE FEMUR

BJARNE LINDÉN

The Department of Orthopaedic Surgery, Malmö General Hospital (University of Lund), Malmo, Sweden

The incidence of osteochondritis dissecans in the condyles of the femur was studied in a defined population and was found to be twice as common in men as in women, the maximum incidence in both sexes being between the ages of 10 and 20 The site of the lesion in the condyles did not differ between age groups The incidence of diagnosed cases has increased somewhat in recent years but only in men The incidence in the population is less than has been suggested in the past

Key words osteochondritis dissecans, femur condyles, incidence

Accepted 22 ix 76

Osteochondritis dissecans in the condyles of the femur is supposed to be a fairly common condition (Aegerter & Kirkpatrick 1969) How common is not known since there is no incidence study available based on a given population The aim of the present study is to describe the incidence of osteochondritis dissecans in the city of Malmo

PATIENTS AND METHODS

The city of Malmo in southern Sweden has a population of about 250 000 There is only one general hospital with one orthopaedic department and one roentgendiagnostic department in the city The health system a fairly stable population and the fact that detailed population data are available have in the past proved that Malmo is well suited for epidemiological investigations

The study embraced all patients with a diagnosis of osteochondritis dissecans in the condyles of the femur The diagnosis was based on a radiogram or on an operative finding Only cases diagnosed before the age of 50 were accepted The study took place between 1965 and 1974 (10 years) and during that period all cases were included which were diagnosed for the first time In the radiogram not only the diagnosis of osteochondritis dissecans was secured but it was also established whether or not the epiphyseal line in the distal end of the femur was closed There are a few radiologists who work privately in the city and their records were also searched for cases of osteochondritis dissecans It was found that cases diagnosed by these radiologists were usually recorded at the hospital and therefore automatically included in the study It must be assumed that at least 95 per cent of all cases of osteochondritis dissecans diagnosed during the period under study are therefore included

All the patients were subdivided according to sex and age Thanks to City Financial Council Committee data concerning the population were obtained for sexes and for age groups representing the average of the period under observation Age and sex specific incidence were calculated, and expressed as the number of patients with osteochondritis dissecans diagnosed in the femoral condyle per 100 000 of the population at risk Standard statistical methods were applied

Financial support was obtained from the Swedish Medical Research Council (project no B 76-17X-2737-08A)

Table 1 Distribution of osteochondritis dissecans in Malmö over the years with regard to age and sex

	1965		1966		1967		1968		1969		1970		1971		1972		1973		1974		Total		
Age	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	
0-9				1		1				1		1			2		1				3	4	7
10-19	7	1	3		3	4	3	6	4	3	5	5	4	3	4	3	10	3	5	3	48	31	79
20-29	2	1	2	2			6	1	2	1	3	1	2	1	5	1	1	1	5		29	9	37
30-39	2	1					2		1	1			2	1	1		2	1	2		12	4	16
40-49	2			2			1		2				1	1	2		3	1	2		13	4	17
	13	3	5	5	3	5	12	7	9	6	8	7	9	6	14	4	17	6	14	3	104	62	156

ESULTS

itween 1965 and 1974 altogether 156 itients with osteochondritis dissecans the femoral condyles were diagnosed the city of Malmo Seventy-eight were cated in the right knee, 69 in the left ee and 9 were bilateral, in all 165 ints The ratio men to women was to 1 The distribution with regard to ge and sex is presented in Table 1 The sions were localized as demonstrated in Figure 1 The age- and sex-specific incidence for the entire period under study are shown in Figure 2 When the cases were subdivided into two 5-year groups according to the time of their diagnosis, there was a significant difference between the first and the second time period in the incidence of osteochondritis dissecans in men ($0.01 > p > 0.001$) (Figure 3) This change was not related to whether the epiphyseal line was closed

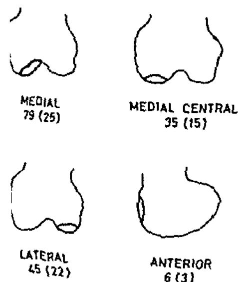


Figure 1 Site of osteochondritis dissecans lesions in the condyles of the femur The number in brackets represents patients who had not closed the epiphyseal line of the distal end of the femur at the time of diagnosis

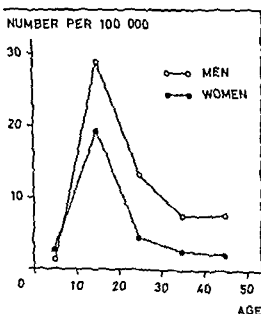


Figure 2 Age and sex specific incidence of osteochondritis dissecans in the femoral condyles in Malmö

Acta orthop scand 47, 664–667, 1976

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Accepted 22 ix 76

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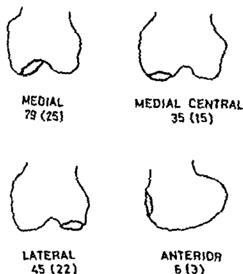


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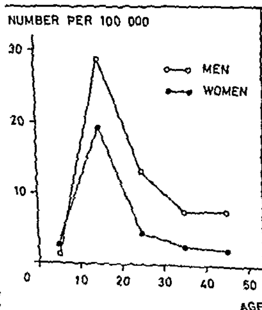


Figure 2 Age and sex specific incidence of osteochondritis dissecans in the femoral condyles in Malmö

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Accepted 22.ix.76

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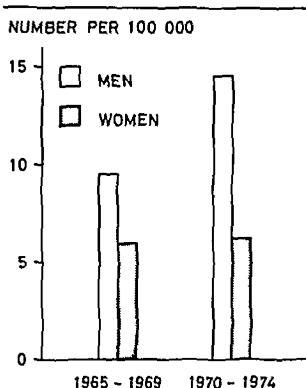


Figure 3. Age and sex specific incidence of osteochondritis dissecans in the distal end of the femur. Comparison between the first and the second part during the period under observation.

or not at the time of diagnosis or to the location of the lesion. There was no such change during this time in women.

DISCUSSION

The age and sex distribution as well as the localization of the lesions are well in agreement with the findings of other authors (Green 1966, Aichroth 1971 and Lindholm 1974). Only a few cases were diagnosed before the age of 10 and the maximum incidence was found between the ages of 10 and 20. Osteochondritis dissecans is twice as common in men as in women and is usually localized in the lateral part of the medial femoral condyle. The localization is smaller in children and adults. The increase in incidence of osteochondritis dissecans is confined to men in this study. The population under the age of 50 was comparatively stable during the years 1965 to 1971, about 175 000, but this decreased slowly to about 157 000 in 1974. Nevertheless the number of diagnosed cases increased in men. The total number of knee radiograms taken in the hospital increased from about 2 500 in 1965 to 7 800 in 1974. This fact of course may account in part for the change in incidence but does not explain why only men would benefit from better diagnostic efforts. An additional explanation is the increasing sports activities in the city. The number of people enrolled in common sports activities such as football has at least doubled in the last 10 years (Nilhus et al. 1976). Such a finding would imply a traumatic origin in some of the osteochondritis cases or at least that it was due to trauma that the condition was being diagnosed. The numbers presented in this study are estimates of minimum incidence. There may be undiagnosed lesions without clinical symptoms which can be revealed only in population studies. The incidence found in our sample was lower than that in past studies (Aegerter & Kirkpatrick 1969). However, taking into account the high risk of gonarthrosis (Lindén 1976), it can be concluded that at least 4 per cent of all cases of so called primary gonarthrosis in men are indeed caused by osteochondritis dissecans earlier in life.

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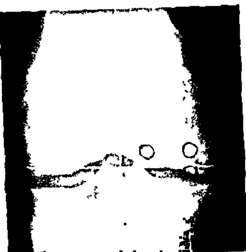


Figure 1 Knee joint with osteochondritis dissecans in the medial femoral condyle Co ordinates and values included in the count of the lesion indicated



Figure 3 Same joint operative finding

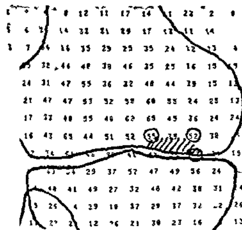


Figure 2 Display of count rates Outline of the femur indicated

only the antero posterior projection was used for the radiography and the uptake measurement The following measurements were calculated

Femur

The average count rates observed over the distal end of the femur including the condyles

Lesion

The average of the three highest count rates observed within the lesion or in the bone next to the lesion (Figure 2) The corresponding site of the contralateral joint was found by turning the outline of the osteochondritis dissecans joint over and superimposing the lesion on the corresponding site on the contralateral side

Lesion/Femur

The ratio of the average count rate of the lesion and the average count rate of the femur as described above

RESULTS

There was no significant difference in the uptake in the femur with the lesion as compared with the contralateral femur (Table 1) There was, however, a significant difference between the lesion and the corresponding site of the contralateral joint The increase of the uptake in the area of the lesion was about 40 per cent The uptake in the lesion corrected for the uptake in the distal end of the femur also differed significantly between osteochondritis and control knees

DISCUSSION

Rosenberg & Zaas (1969), Bieschell (1973) and Smillie (1974) suggest that osteonecrosis is the osteochondritis dis-

Acta orthop scand 47, 668–671, 1976

STRONTIUM-85 UPTAKE IN KNEE JOINTS WITH OSTEOCHONDRITIS DISSECANS

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The uptake of Strontium 85 in the distal end of the femur and in the immediate vicinity of the lesion was measured in 12 young men with osteochondritis dissecans The uptake was significantly but only slightly increased It was confined to the area of the lesion was less than observed in early cases of gonarthrosis and an order of magnitude less than in cases of osteonecrosis It is concluded that the repair process of osteochondritis dissecans is very slow and involves only a minor part of the bone tissue surrounding the lesion

Key words osteochondritis dissecans, Strontium 85 bone, knee joint

Accepted 13 ix 76

In spite of the vast amount of research invested in the field of radio-nuclides and bone there are no data available on tracer studies on osteochondritis dissecans using bone-seeking radio-nuclides

The object of the present study was to investigate the uptake of Strontium-85 in a series of cases with osteochondritis dissecans in the femoral condyle

PATIENTS

Included in the study were 12 otherwise healthy men between 17 and 39 years old (average age 25) with osteochondritis dissecans in the medial femoral condyle The contralateral knee joint was clinically and radiologically normal in all cases The study was performed just after the radiological diagnosis of the osteochondritis was obtained However, at the time of the diagnosis there was a history of knee symptoms in the patients ranging from 1 month to 17 years with an average of 5 years The osteochondritis lesions were, in all instances, located in the medial femoral condyle and the size of the lesions varied between 0 5 and 2 5 centimeters measured as the maximal width on an antero posterior film of the knee There were no cases of the lesions sequestered to a loose body

METHOD *

All the patients received an intravenous injection of 100 μCi Strontium 85 Two weeks later both knee joints were measured using the digital step scanning technique described by Bauer & Smith (1969) With the patient on a stretcher in the supine position a scintillation detector with a focusing collimator was moved over the knee joints After measuring the activity of the Strontium 85 incorporated in bone a radiogram was obtained with the knees in the same position By means of a co ordinate system the data on uptake of tracer could be related to the anatomy of the knee joint as demonstrated in Figures 1 and 2 Both knees were measured but

Financial support was obtained from the Swedish Medical Research Council (project no B 76 17X-2737-08 A)

* The scintimetry was performed in the Department of Roentgen Diagnostics II Lund University Hospital

dyles In *Osteochondritis dissecans* Dissertation University of Lund
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Table 1 Uptake of Strontium 85 in osteochondritis dissecans

	n	OD joint M ± SD	Contralateral joint M ± SD	t-test of paired observations
Femur	12	25 9 ± 12 7	22 5 ± 10 9	$p > 0\ 05$
Lesion	12	38 1 ± 14 1	26 7 ± 7 8	$0\ 01 > p > 0\ 001$
Lesion/Femur	12	1 57 ± 0 41	1 27 ± 0 25	$0\ 05 > p > 0\ 01$

Table 2 Highest values recorded in the femoral condyles compared with Ahlbäck et al 1968 (Average ± SE)

	Ahlbäck et al	Present study
Normal joints	48 ± 5	45 ± 6
Early gonarthrosis	76 ± 5	–
Osteonecrosis	181 ± 18	–
Osteochondritis	–	53 ± 7

secans of the elderly However, Ahlbäck et al (1968) found that osteonecrosis is a separate entity which differs from osteochondritis dissecans not only in the age of onset but also in the symptoms, the radiographic appearance and the location In the present study, we have demonstrated that osteochondritis dissecans also differs from osteonecrosis with respect to the uptake of bone-seeking tracer The increase is comparatively small whereas in osteonecrosis there is, almost always, an impressive increase in the uptake of tracer which can be observed early in the disease and which may provide the diagnosis prior to the radiological appearance of the lesion

In order to compare with previous authors (Ahlbäck et al 1968) the highest single uptake recorded over the femur condyles was also calculated for our series of osteochondritis patients (Table 2) The uptake of tracer measured in this way in normal knee joints is the same in our study as in the study of Ahlbäck et al (1968) Calculated in this way, the uptake in the osteochondritis knee joint is only slightly elevated over that of normal joints It is significantly less than in the cases of early osteoarthritis where the diagnosis was based on narrowing of the joint space in films obtained from patients who were standing and it is only a fraction of the uptake recorded in cases of osteonecrosis

Chiroff & Cooke (1975) demonstrated that there was a thin layer of enchondral bone formation facing the osteochondritis lesion From our data it seems that the rate of this formation is only slightly elevated over the rate normally observed in this region Therefore, it may not be a sign of a true reaction of repair

Later in the development of osteochondritis dissecans in adults, gonarthrosis is a frequent complication (Lindén 1976) These changes are, however, usually delayed for 20 years or more after the diagnosis of the lesion Since these patients were all measured soon after the diagnosis, secondary gonarthrosis could not be expected and was not found Therefore, there were no signs of a generally increased uptake in the joint as has been demonstrated in joints with gonarthrosis (Bauer & Smith 1969)

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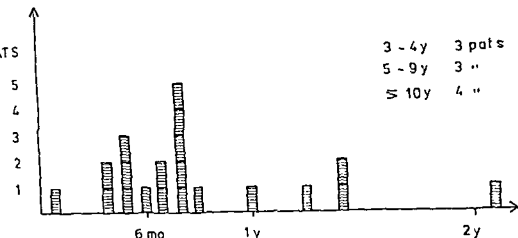


Figure 1 The interval between meniscectomy and postoperative rearthrography in 30 patients with unsatisfactory recovery

RESULTS

The patients were divided into five groups, according to the etiological factor (Table 1)

Table 1 Cause of unsatisfactory postmeniscectomy recovery in 30 patients

Incorrect therapy	4
Ineffective therapy	11
Another lesion	10
Delayed recovery	3
Late osteoarthritis	2

Incorrect therapy (4 patients) In three patients another lesion explaining the symptoms was found in two cases it was a rupture of the medial collateral gament and in one case chondromalacia f the patella In all these the preoperative arthrogram had been negative and he meniscus intact at operation In one patient a rupture of the medial meniscus had been clinically and roentgenologically diagnosed in another hospital, but an intact meniscus was found at operation, and retrospectively the arthrogram can be regarded as negative (Figure 2) In this case we were not able to explain the patient s knee symptoms

Ineffective therapy (11 patients) The cause of postoperative symptoms was, in nine cases, a retained fragment of the posterior horn of the medial meniscus and in two cases a fragment of the lateral meniscus The remnant was always more than 10 mm long in 10 patients it was infiltrated by contrast medium indicating degenerative changes, and in seven there was a rupture in the remnant (Figure 3) In the patient without degenerative changes in the remnant, the rearthrogram was made 1 month postoperatively Eight of these patients have already been



Figure 2 A radiograph of the medial meniscus corpus The oblique projection with overlying facets of the meniscus may have led to an erroneus rupture diagnosis

Acta orthop scand 47, 672-675, 1976

WHY A MENISCECTOMY FAILS

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The clinical and roentgenological data on 30 patients with unsatisfactory recovery or recurrent symptoms after meniscectomy were analyzed The meniscectomy was regarded as having been the wrong choice of therapy in four patients and as ineffective therapy in 11 In 10 patients other knee lesions dominated postoperatively, in three the recovery was delayed for no obvious reason but the symptoms slowly disappeared and in the remaining two patients a degenerative osteoarthritis developing some time after the meniscectomy was regarded as the cause of the recurring symptoms We conclude that with an optimal clinical and arthrographic analysis and with careful operative technique as many as 17 arthrotomies (out of 30 primary and 13 reoperations) in the material presented could have been avoided

Key words arthrography, arthrotomy, knee injuries semilunar cartilages

Accepted 27 viii 76

An unsatisfactory recovery or recurring knee symptoms after a meniscectomy present the clinician with a problem, especially when he also has to consider the indications for a rearthrotomy (Schaefer 1953, Schilling 1963)

Arthrography can provide valuable support in the solving of the problem but even the findings in a postoperative arthrogram are not conclusive evidence (Fischedick 1963, Thiemann & Fischer 1970, Debnam & Staple 1974)

In our hospital an unsatisfactory post meniscectomy recovery is as a rule re-evaluated with double-contrast arthrography In trying to discover "why a meniscectomy fails", we have made a clinical and roentgenological analysis of the pre- and postoperative data on a series of patients with unsatisfactory postmeniscectomy recovery

PATIENTS AND METHODS

From 714 arthrographies made during a 2 year period from March 1973 to March 1975 we have selected the 30 meniscectomized patients with one or two postoperative arthrograms The age of these patients ranged from 16 to 59 years 18 were men and 12 women

A primary arthrogram had not been carried out in eight cases seven of the patients having been operated upon before 1970 Again in eight cases the primary operation had been performed elsewhere but in these cases too the aim had been a total meniscectomy The rearthrography and rearthrotomy have in all cases been carried out in our hospital the total number of reoperations required being 13 eight of which have already been performed Of these 13 patients eight had undergone the primary operation in our hospital and five elsewhere The time interval between the first operation and the postoperative arthrography is presented in Figure 1

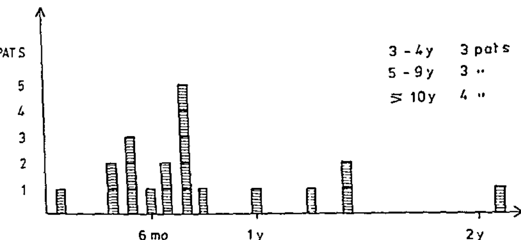


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Ineffective therapy (11 patients) The cause of postoperative symptoms was, in nine cases, a retained fragment of the posterior horn of the medial meniscus and in two cases a fragment of the lateral meniscus The remnant was always more than 10 mm long, in 10 patients it was infiltrated by contrast medium indicating degenerative changes, and in seven there was a rupture in the remnant (Figure 3) In the patient without degenerative changes in the remnant, the rearthrogram was made 1 month postoperatively Eight of these patients have already been



Figure 2 A radiograph of the medial meniscus corpus The oblique projection with overlying facets of the meniscus may have led to an erroneous rupture diagnosis



Figure 3. (A) A radiograph from the border of the medial meniscus corpus and the posterior horn. An insignificant remnant, but also an elongated piece of meniscus centrally from it, indicating a remnant of the whole posterior horn with a rupture in it (postoperative arthrogram I). (B) Almost the same projection of the same knee after reoperation. Good result (postoperative arthrogram II).

reoperated, and three are awaiting reoperation.

Another lesion dominating postoperatively (10 patients). The meniscus lesion was *obvious in all cases at the* primary operation, and significant relief of the symptoms was experienced postoperatively. In three patients there was a concomitant traumatic lesion, in two instances a tear of the other meniscus and in one instance a tear of the anterior cruciate ligament. The latter was sutured in the primary operation but still causes problems, and the patients with a tear in the other meniscus are awaiting reoperation. *In two patients there had been a* new trauma after the operation, in both, *the rearthrogram revealed a minimal* remnant of the meniscus and the patients recovered slowly without any reoperation. In five patients symptoms of early degenerative osteoarthritis were already present, either during the primary clinical investigation (1 patient) or soon after the meniscectomy (4 patients). Dissecting osteochondritis was *found to* be the cause in three cases, chondromalacia of the patella in one case, and an unexplained early femoropatellar osteoarthritis in the remaining case. Two of these patients were active sportsmen.

Delayed recovery (3 patients). A medial meniscus tear had been successfully operated and a minimal remnant was seen on the rearthrogram made 5–12 months postoperatively. However, pain symptoms during heavy labor and *sporting activity persisted, without diag*nostic signs. In all three patients the symptoms gradually disappeared without reoperation. In one of these a hemarthron and a deep venous thrombosis of the same leg were diagnosed as postoperative complications.

Late degenerative osteoarthritis (2 patients). After a long symptom-free period, these two patients complain, 9 and 13 years postoperatively, of slowly *increasing symptoms which can be at*tributed to osteoarthritis. The symptoms *are worse in the operated knee,* and especially bad in the operated compartment.

DISCUSSION

Patients can usually return to work 1–2 months after meniscectomy although *there may be minimal symptoms or some* limitation of movement up to 6 months postoperatively (Bohler 1955). The surgeon will therefore need great experience in order to recognize the necessity and the right time for a thorough re-evaluation, including arthrography. In our material, the peak number of arthro-

graphies has been carried out 4 to 9 months postoperatively

The correlation of a positive arthrogram and the operative finding is usually high (Bessler 1965 Ricklin et al 1971) The necessity for meniscectomy with a negative arthrogram has to be reconsidered very carefully, especially if some other possible reason for the symptoms is present (Wilppula & Vahvanen 1971)

In the largest patient group (11/30) of our material the symptoms were caused by a remnant of the posterior horn of the operated meniscus If the totality of the meniscectomy is in doubt during operation the surgeon should always consider an additional posterior approach to remove the remnant under visual control In postoperative arthrography it is difficult to differentiate between a remnant and a regenerate The length of the remnant (more than 10 mm) the infiltration by contrast medium and a rupture in the remnant are all indicative of a remnant with clinical significance (Fischedick 1963 Thiemann & Fischer 1970)

A high occurrence of osteoarthritis in postmeniscectomy knees has been reported both clinically (Jackson 1967 Tapper & Hoover 1969) in the radiographs (Appel 1970) and in arthroscopically examined material (Dandy & Jackson 1975)

A combined clinical and radiological investigation can clarify the cause of postoperative symptoms in 90 per cent of cases The value of rearthrography is beyond dispute especially when a rearthrotomy is being considered With a critical appraisal of the indications and with a careful operative technique as many as 17 of our 43 arthrotomies (30 primary + 13 rearthrotomies) might have been avoided (17 = 4 primary with wrong indications + 11 rearthrotomies for removing the remnant + 2 rearthrotomies for removing the second also ruptured meniscus)

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Figure 3 (A) A radiograph from the border of the medial meniscus corpus and the posterior horn An insignificant remnant, but also an elongated piece of meniscus centrally from it indicating a remnant of the whole posterior horn with a rupture in it (postoperative arthrogram I) (B) Almost the same projection of the same knee after reoperation Good result (postoperative arthrogram II)

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Figure 1 The lower limbs in Case A with a lymphangiogram showing primary lymphatic hypoplasia are illustrated

Figure 2 The same features as in Figure 1 are illustrated in Case B

Diagnosis and Management

Septic arthritis of the knee was suspected clinically by the usual signs of heat swelling and severe pain on attempted movement of the joint The assessment of joint effusion was difficult as the circumference of the knee was already increased by lymphoedema Blood cultures were negative Intra articular injections of antibiotic were not given nor was joint aspiration used to monitor the bactericidal activity of

Acta orthop scand 47, 676–679, 1976

SEPTIC ARTHRITIS IN ASSOCIATION WITH PRIMARY LYMPHOEDEMA

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The association between b haemolytic streptococcal arthritis of the knee and primary lymphoedema is reported This condition appears to resolve slowly using conventional methods of treatment in the form of immobilisation and antibiotic therapy However, the penetration of penicillin into the joint in these two patients was adequate, suggesting that there is no place for the intra articular injection of antibiotic in the treatment of this condition

Key words infectious arthritis, lymphoedema

Accepted 20 x 76

Septic arthritis is a rare condition, usually presenting as a complication of rheumatoid arthritis The commonest causative organism is a staphylococcus Diagnosis by joint aspiration and bacteriological culture with appropriate antibiotic treatment and splintage of the joint usually results in resolution of the infection within a few days or weeks

Two cases of septic arthritis in association with primary lymphoedema have recently been seen at the Middlesex Hospital In both cases the organism grown was b-haemolytic streptococcus This association has not previously been described The infection was slow to resolve in both cases The difficulties experienced in the management of these cases are discussed with particular reference to the role of antibiotics

CASE REPORTS

Case A Six months after a right Thompson medial buried dermis flap procedure (Thompson 1967) had been performed on a 69 year old woman with an 8 year history of primary bilateral lower limb lymphoedema she was re admitted with a 1 week history of pain and swelling of the right knee On aspiration of the knee 20 ml of purulent fluid was obtained which on culture grew b haemolytic streptococci The joint was immobilised and antibiotic treatment started in the form of 4 mega units of penicillin 1 gm orally q d s Four days later she was apyrexial and the antibiotic regimen was changed to penicillin G 2 mega units intra muscularly for a further 2 weeks, after which maintenance therapy (penicillin V 500 mgm orally q d s) was continued for 4 months The knee however remained painful and swollen for several weeks and was still causing discomfort 6 months later (Figure 1)

Case B A 64 year old woman with longstanding primary bilateral lower limb lymphoedema was admitted with a 1 week history of pain and swelling of the right knee Forty ml of purulent fluid obtained on aspiration grew b haemolytic streptococci The knee remained clinically infected and a low grade pyrexia continued for 1 month despite immobilisation of the knee and the administration of penicillin G 2 mega units intramuscularly q d s Five months later she also reported persistent discomfort in the knee (Figure 2)

levels in the synovial fluid of the affected knees (Figure 3) The results show that even under these circumstances the bactericidal activity within the knee was in a 1 1 ratio to that in the blood

In neither case was there a recurrence of infection The duration of symptoms before starting treatment was 7 days in both patients Russell & Ansell (1972) noted a high recurrence rate if there was a delay in diagnosis of more than 2 weeks

ACKNOWLEDGEMENTS

We are very grateful to Mr D R Sweetnam and Mr Noel Thompson for their advice in preparing the manuscript

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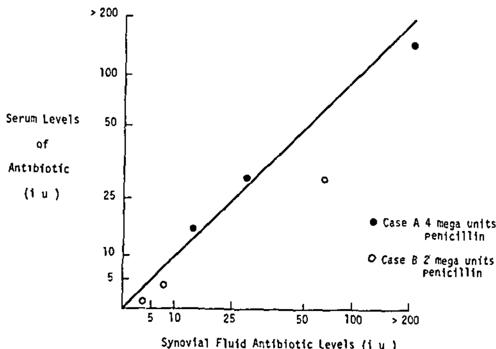


Figure 3 The relationship between the levels of benzyl penicillin in the serum and that in the synovial fluid of the affected knees

penicillin within the joint, because of the risk of re-introducing organisms into the joint Despite adequate antibiotic cover and immobilisation, the knees remained clinically infected for 1 month and were still painful and stiff 6 months later

DISCUSSION

The b-haemolytic streptococcus seldom causes septic arthritis—about 7 per cent in most series (Russell & Ansell 1972, Kelly et al 1970, Bartch 1962) It is, however, the commonest causative organism of cellulitis in patients with lymphoedema (Yoffey & Courtice 1956) In both the reported cases the septic arthritis was preceded by cellulitis In the first patient the entry of the organism into the joint may have been facilitated by the Thompson buried dermis flap procedure (Thompson 1967) as the shaved flap is rolled into the deep compartment of the leg and sutured to the capsule of the knee joint This complication has not, however, been previously noted In the second patient the deep fascia was intact, but it is possible that the organism entered by direct invasion, as the superficial lymphatics on the lateral side of the knee joint, albeit extra-fascial, pass close to the joint, or alternatively, the patient may have been one of the 30 per cent in whom it is known that lymph from the short saphenous system drains into the deep popliteal group of lymph nodes which lie close to the posterior aspect of the joint (Pflug & Calnan 1971)

Parker & Schmid (1971) showed a linear relationship between the antibiotic level in synovial fluid and that in the blood Although there is no evidence that giving intra-articular antibiotics with concentrations of over 100 times the minimum bactericidal concentration renders greater benefit than the 5 20 times that can be achieved parenterally, it was felt that in the cases described, the slower resolution of the infection might be due to impaired penetration of antibiotic into the knee of a lymphoedematous limb Therefore, 6 months after the infection had settled, the serum benzyl penicillin levels were measured and related to the

levels in the synovial fluid of the affected knees (Figure 3) The results show that even under these circumstances the bactericidal activity within the knee was in a 1 1 ratio to that in the blood

In neither case was there a recurrence of infection The duration of symptoms before starting treatment was 7 days in both patients Russell & Ansell (1972) noted a high recurrence rate if there was a delay in diagnosis of more than 2 weeks

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Acta orthop scand 47, 680-685, 1976

DISTAL DISINERTION OF THE PATELLAR LIGAMENT COMBINED WITH AVULSION FRACTURES AT THE MEDIAL AND LATERAL MARGINS OF THE PATELLA

A Case Report and an Experimental Study

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A 12-year-old boy presented with a proximally retracted patella 5 months after an injury to the left knee The clinical and radiographic features and the findings at operation led to the conclusion that the original lesion had been a distal disinsertion of the patellar ligament combined with avulsion fractures at the medial and lateral margins of the patella produced by the medial and lateral longitudinal patellar retinacula Loading experiments on amputation and cadaver specimens showed that these retinacula apart from being tendons for the vastus medialis and the vastus lateralis, respectively, constitute a direct fibrous connection of considerable strength between the patella and the tibia and thus are capable of producing avulsion fractures

Key words avulsion fracture patella, retinaculum clinical and experimental study

Accepted 26 viii 76

Avulsion fractures at the medial and lateral margins of the patella produced by the medial and lateral longitudinal patellar retinacula seem to be little known Indeed, an extensive search in the literature has failed to reveal any previous report of such a case Most anatomical textbooks and handbooks describe the medial and lateral longitudinal patellar retinacula as tendinous structures which directly connect the vastus medialis and the vastus lateralis, respectively, to the tibia, but omit to mention that they also, like the patellar ligament, connect the patella to the tibia (Figure 1) An exception is Callander's Surgical Anatomy (Anson & Maddock 1958) where this fact is clearly stated Indeed, the bond between the patella and the tibia through the medial and lateral longitudinal patellar retinacula is very strong as will be shown below by a clinical case and by loading experiments on amputation and cadaver specimens

CASE REPORT

A 12 year old boy fell from a tree and sustained an injury to the left knee At hospital 30 ml of blood was aspirated from the joint and an elastic bandage was applied Radiographs revealed a rounded fragment of bone lateral to the apex of the patella (lower thin arrow in the

oblique projection in Figure 2), it was interpreted by the radiologist as being possibly either the result of an old fracture or a patella bipartita (Other abnormalities as shown in Figure 2 were not noticed at that time) Five weeks after the injury it was noted that the boy was unable to extend the knee fully, the deficit was about 15°. Five months after the injury it was recognized that the left patella was retracted upwards and there was a protrusion anterior to the upper end of the tibia, the patient could still not extend the knee fully New radiographs were taken (Figures 3 and 4) and compared with those made immediately after the injury (Figure 2) This comparison, together with the clinical picture and the findings when the knee was later operated upon, permitted the conclusion that the original lesion had been a distal disinsertion of the patellar ligament combined with avulsion fractures of the patella produced by the medial and lateral longitudinal patellar retinacula (Figure 5) In the Figures 2, 3 and 4 the fragments avulsed from the lateral margin of the patella have been marked by thin arrows, whereas the fragment avulsed from the medial margin has been marked by a thick row The fragments had grown and obtained more evident bony structure during the 5 onths that had elapsed after the injury During this time too, two pieces of bone had formed the disinserted end of the patellar ligament sterisk in Figures 3 and 4) At the operation e lowermost of these was fastened by a screw the tibial tubercle, once the patella and the atellar ligament had been drawn down into a orrect position, the other was removed, as were lso the fragments that had been avulsed from he patella by the retinacula The knee was immobilized for 6 weeks in a plaster cast extending rom the groin to the malleoli At clinical fol ow up 3 years after the operation the patient was free from discomfort There was a slight prominence corresponding to the tibial tubercle The range of mobility of the knee was normal The extension force of the knee and the circumference of the thigh were the same as on the uninjured side Radiographs showed a slightly enlarged tibial tubercle without fragmentation, its epiphyseal line had closed The position of the patella was the same on both sides

LOADING EXPERIMENTS

In order to demonstrate that the medial and lateral longitudinal patellar retinacula, apart from being tendons for the vastus medialis and the vastus lateralis, also constitute a direct fibrous connection between the patella and the tibia of sufficient strength to produce avulsion

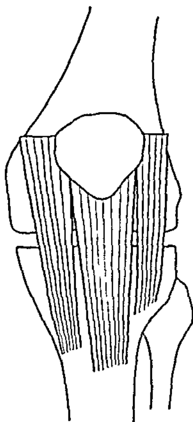


Figure 1 The medial and lateral longitudinal patellar retinacula, apart from being tendons for the vastus medialis and the vastus lateralis, respectively also constitute a direct fibrous connection between the patella and the tibia

fractures, the following experiments were carried out One amputation specimen and four cadaver specimens were prepared and subjected to an increasing load according to the principle illustrated in Figure 6 The patellar ligament, whose borders can be easily identified, was cut through transversely, after which the only structures connecting the patella to the tibia [illegible] tension to failure on a modified standard material testing machine (Alwetron universal testing machine Model T-2000 Figure 7) The extension rate was 50 mm/min The failure consistently occurred in

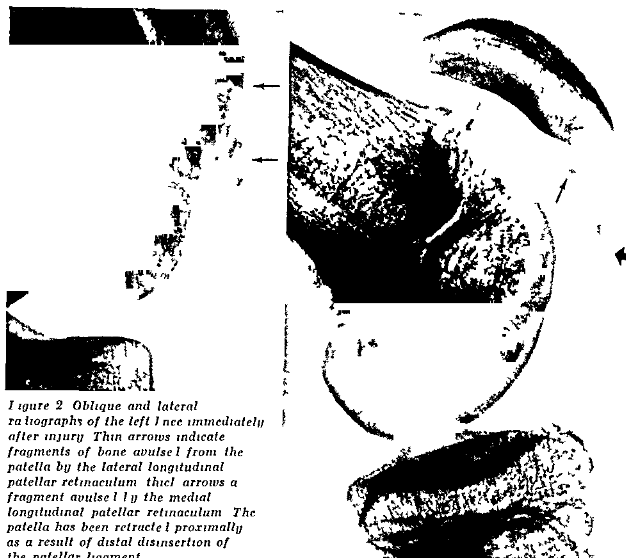


Figure 2 Oblique and lateral radiographs of the left knee immediately after injury. Thin arrows indicate fragments of bone avulsed from the patella by the lateral longitudinal patellar retinaculum; thick arrows a fragment avulsed by the medial longitudinal patellar retinaculum. The patella has been retracted proximally as a result of distal disinsertion of the patellar ligament

the retinacula, never in the bone. The results are given in Table 1

Table 1 Results of loading experiments

Sex	Age (years)	Maximum load (Newton) at failure
M	38	1130
M	62	930
M	55	880
M	60	1400
M	62	1200

DISCUSSION AND CONCLUSION

If lateral radiographs in a case of traumatically produced patella alta reveal bone fragments distal to the patella and there is no corresponding defect at the apex (cf. Figure 2), avulsion fractures produced by the longitudinal patellar retinacula should be suspected. Further information can then be obtained by oblique projections exposing the medial and lateral borders of the patella and by a "sky line" projection as in Figure 4. If the correct nature of the injury is not recognized from the start, the fragments might later be misinterpreted as loose bodies.

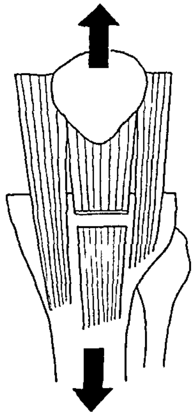
In the loading experiments the deformation rate was relatively slow. Using a more rapid rate that would simulate an actual injury the retinacula would prob

Figure 3 Oblique and lateral radiographs 5 months after injury Thin arrows indicate pieces of bone formed from the fragments avulsed by the lateral longitudinal patellar retinaculum thick arrows a piece of bone formed from the fragment avulsed by the medial longitudinal patellar retinaculum (compare with Figure 2) Asterisks indicate two pieces of bone formed at the distal end of the uninserted patellar ligament (compare with lateral view in Figure 2)



Figure 4 "Sky line" view of the knee 5 months after injury (For indications see text to Figure 3)

Figure 6 The principle for the loading experiments After division of the patellar ligament the only structures opposing distension of the specimen are those parts of the medial and lateral longitudinal patellar retinacula that are attached to the patella



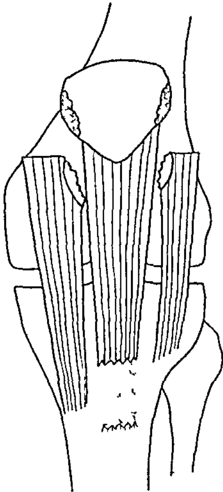


Figure 5 The lesion in the reported case distal disinsertion of the patellar ligament and avulsion fractures of the patella produced by the medial and lateral longitudinal patellar retinacula



Figure 7 Cadaver specimen prepared according to Figure 6 is being tested in tension to failure on an Alwetron testing machine

ably have tolerated even more load before failure (cf Noyes et al 1974) The results of the loading experiments show that the medial and lateral longitudinal patellar retinacula are strongly attached to the patella and are thus capable of producing avulsion fractures when the extension apparatus of the knee is forcibly overloaded

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Acta orthop scand 47, 686-689, 1976

OPEN REDUCTION OF CENTRAL COMPRESSION FRACTURES OF THE TIBIAL PLATEAU

Preliminary Report of a New Method and Device Arrangement

H G Edeland

Department of Orthopaedic Surgery, Central Hospital, Molndal, Sweden

A new method of reduction and fixation of a uniformly depressed fracture of the tibial condyle is described A curved steel probe, introduced through a cortical window in the uninjured condyle, is used to reduce the fracture fragments as well as to compact the fracture region (TV-monitored x-ray projectioning is desired) The instruments needed for the operative procedure are as follows a probe for reduction and compaction, a tube and a plunger for deposition of bone transplants, and a forked plate Five cases in which the curved probe reduction method has been used are reported

Key words ceramic material, fixation, fractures, tibial condylar fractures

Accepted 13 ix 76

A fracture of one of the condyles of the tibia is not an uncommon injury, more often occurring laterally than medially, and mostly in the elderly osteoporotic patient (Rasmussen 1973) The uniformly depressed central condylar fracture with an intact cortical rim (Hohl Type I B) represents 26 per cent of the entire tibial condylar fracture group (Hohl 1967) Several of these fractures will benefit from the method of treatment outlined below

In a forced valgus position of the knee the lateral femoral condyle is wedged down upon the corresponding tibial condyle In this way, the femoral condyle depresses and compresses the central parts of the tibial plateau thus fracturing the surface in a mosaic-like manner but often sparing the outer border of the condyle and the meniscus (Kennedy et al 1968) (Figure 1)

As stressed by several authors (Hohl 1967, Maquet et al 1967, Rasmussen 1973), the fracture deformity produced by a central fracture of one of the tibial condyles, can only be tolerated for a short time, and it can only, to a limited extent, be compensated biomechanically by fibrous callus

PATIENTS

Five patients have been operated on according to the method outlined below In four patients the lateral condyle was fractured in the fifth the medial condyle In all cases the central compressions amounted to or exceeded one cm and the knee was unstable in the extended position Three patients were women two men All patients were more than 55 years old In

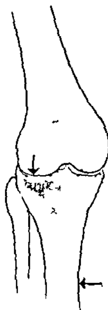


Figure 1 I r e l valg s pos t on of the knee aus ng a central lepression of the lateral t bial plateu

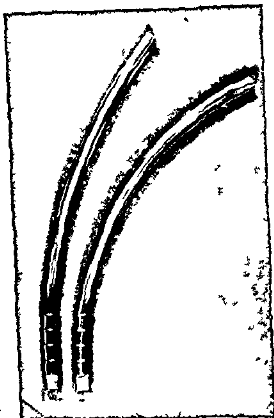


Figure 2 T o probes vith d fferent curvatures

one patient the fracture reg n as stabil ze l by two lo ps of wire from the lateral to the me l al de of the tib al condyle Autol g s bone t ansplantation was performed n two pat ents

METHODS

aim of the method deser b d below is to stablish in a simple way the all important p rt f the femoral condyle and consequently tabil ty of the knee joint This will pre ent otherwi e na oidable joint insuff ciency to in reased load with the forces con erg ng liml e l parts of the tibial condyle resulting grad ally increas ng strains on the ligaments The method requires a c rved steel prol e ch has a d ameter of 1 0–1 5 cm a length of 20 and a ra l of the c rve of approximately cm The re lu tion end of the prol e is ghtl c nca e The instrument with various r atures l ll u trat d in Figure 2

Th probe is intro luce l into the bone via a ne t a n in the s l condylar cortex of the nfra t re l si le of the t l lal head o that the r l w ll not affe t the s pporting cortical arts of the fra ture l condyle The conca e red tl n nd of the probe is placed in po i on l eneatl the compressed parts of the c n l l n ler TV monitored x ray control The c mpress d fracture region is reduced by re peated careful p shes of the prol e (I ig re 3) On its way the prol e transfers an l compacts consideral le am nts of cancellous bone from the region l eneath the depressi n The curvature of the prol e permits some s ving" and this makes some minor a ljustments of the reduction possil le and also compacts an l forms trans verse b ne l ri lges imme liately beneath the fracture parts This stal ilizes the re luced frac ture parts The redu tion may if necessary be further stab lized l y several methods of internal fixation e g l y a wire technique described by Cottfries et al 1971) or l y a plate levice especially des gne l for this purpose (Fig re 4) Only a short skin incision is needed for the reduction procedure The s rgery sho ld be per formed w th the fractured leg sligl tly extended The pr operati e set up is illustrated in Figure 5 A full length circular knee cast shoul l be ed for 4 to 6 weeks p st operati ely in order t keep the fract re l knee joint compartment protected

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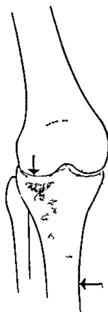


Figure 1 Forced valgus position of the knee causing a central depression of the lateral tibial plateau

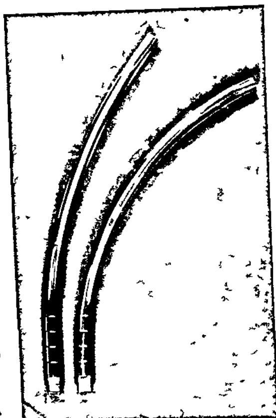


Figure 2 Two probes with different curvatures

one patient the fracture region was stabilized by two loops of wire from the lateral to the medial side of the tibial condyle Autologous bone transplantation was performed in two patients

METHODS

The aim of the method described below is to re establish in a simple way the all important support of the femoral condyle and consequently stability of the knee joint This will prevent otherwise unavoidable joint insufficiency e to increased load with the forces converging limited parts of the tibial condyle resulting gradually increasing strains on the ligaments The method requires a curved steel probe hich has a diameter of 1 0–1 5 cm a length of 20 n and a radius of the curve of approximately cm The "reduction end" of the probe is ightly concave The instrument with various rvatures is illustrated in Figure 2

The probe is introduced into the bone via a enestration in the subcondylar cortex of the infractured side of the tibial head so that the probe will not affect the supporting cortical parts of the fractured condyle The concave red ction end of the probe is placed in pos ion beneath the compressed parts of the condyle under TV monitored x ray control The compressed fracture region is reduced by repeated careful pushes of the probe (Figure 3) On its way the probe transfers and compacts considerable amounts of cancellous bone from the region beneath the depression The curvature of the probe permits some swing" and this makes some minor adjustments of the reduction possible and also compacts and forms transverse bone bridges immediately beneath the fracture parts This stabilizes the reduced fracture parts The reduction may if necessary be further stabilized by several methods of internal fixation e g by a wire technique described by Gottfries et al (1971) or by a plate device especially designed for this purpose (Figure 4) Only a short skin incision is needed for the reduction procedure The surgery should be performed with the fractured leg slightly extended The pre-operative set up is illustrated in Figure 5 A full length circular knee cast should be used for 4 to 6 weeks post-operatively in order to keep the fractured knee joint compartment protected

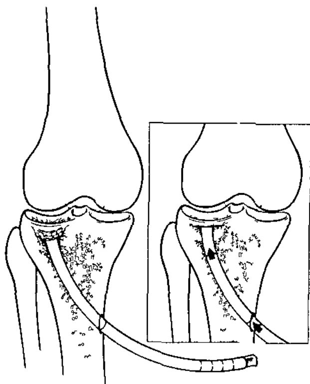


Figure 3 Principle of the fracture reduction and compaction procedure with a curved probe

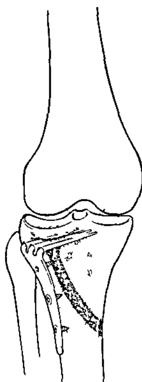


Figure 4 Outline of the support plate applied to a reduced condylar fracture region with bone grafts and/or ceramic material filling the bone defects

RESULTS

All patients were followed up for at least six months, three for more than a year A satisfactory joint function with an active flexion capacity of up to 90 degrees and with full or almost full extension capacity was noted in all cases

A post operative depression of 5 to 10 mm of the reduced area occurred in one case This re dislocation occurred within the first two months after surgery Due to subjectively incapacitating valgus instability of the knee this patient uses a walking stick and a short knee brace



Figure 5 The per operative set up with the C bow x ray apparatus in position for an A P central beam projection of the knee joint space This necessitates a free hanging extremity which should be slightly extended Note that the probe is put into the side of metaphysis contralateral to the fractured condyle

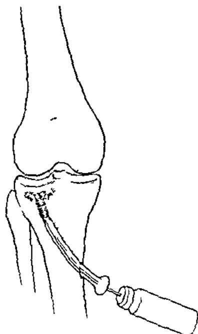


Figure 6 Principle of the use of the bone graft and/or ceramic loaded tube and plunger instrument set up

All patients had sagittal stability Two patients (one mentioned above) had some valgus instability All patients were able to use stairs No-one was troubled by night pains One patient had permanent joint swelling There have been no infections or serious general complications, such as venous thrombosis or pulmonary embolism

DISCUSSION

The method described is probably only suitable for the treatment of uniformly depressed central condylar fractures The alternative to the selected method would have implied a wider approach to the
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ard method usually includes visual control of the reduction through an arthrotomy Meniscectomy would probably have been performed in order to facilitate the reduction of the fracture fragments even if the meniscus was not ruptured primarily It is suggested that by using the above method, arthrotomy, bone grafting and meniscectomy could be avoided

Instead of bone grafts to compensate for the bone defects, porous ceramic material could be used as suggested by Benum et al (1976) and Cameron et al (1976) The ceramic material (e g tricalcium phosphate) could be introduced into the bone defect region by the use of a cylinder and piston type of instrument arrangement, as shown in Figure 6

ACKNOWLEDGEMENT

The drawings were made by Fredrik Johansson Goteborg Sweden

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Acta Orthopaedica Scandinavica

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